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Knowledge Exchange Behavior in Supply Channel Relationships: A Social Exchange and Game-theoretic Approach

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Knowledge Exchange Behavior in Supply Channel Relationships:

A Social Exchange and Game-theoretic Approach

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Abstract

Knowledge exchange behavior is often portrayed as a key determinant of the competitive position of a firm operating in a knowledge intensive environment. Of interest to researchers and managers alike are the conditions that promote, attenuate or even retard knowledge sharing between firms. This research employs a supply channel context to study knowledge exchange behavior (KEB). Whether knowledge exchange occurs, and if so, to what extent, may be contingent on various factors.

While inter-organizational trust has widely been posited to be a key antecedent of knowledge exchange behavior, a review of the literature reveals that the evidence is conflicting. Sometimes a high level of inter-organizational trust may not be necessary for a decision to exchange valuable knowledge. Likewise, despite high inter-organizational trust KEB may not be present.

A recent empirical study by Kim, Umanath, Kim, Ahrens & Kim, (2012) found that increasing levels of inter-organizational trust actually resulted in inhibition of knowledge exchange behavior in supply channel dyads even with a high level of knowledge complementarity. This specific finding has served as the springboard for this project; that is, this inquiry is focused on identifying conditions that render inter-organizational trust unimportant. In short, this research seeks to examine the contingent effect of knowledge interdependence (joint dependence + dependence asymmetry) on KEB – speculated to be a missing contingency by Kim, et al (2012).

In this research project, the role of inter-organizational trust is examined by using game theory to characterize the incentives associated with knowledge sharing. Social exchange theory, along with the relational and social capital perspectives, is used to complement the *game-theoretic view by characterizing the behavioral implications of the incentive structure for each actor in a supply channel dyad.*

A research model is proposed and tested using data obtained in a lab experiment conducted at two sites. The findings suggest that inter-organization trust has little, if any, effect on knowledge sharing behavior when interdependence is high or low. However, the impact of inter-organizational trust on knowledge exchange behavior is significant when interdependence is moderate. The theorized role of dependence asymmetry in the research model is not empirically supported. An ex post analysis sheds some light on the effect of dependence asymmetry in the model.

Keywords: Knowledge exchange, Supply chain management, Knowledge complementarity, Interdependence, Inter-organizational trust, Game theory, Social exchange theory, Relational view, Social capital

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1. Introduction and Motivation

This section presents an overview of knowledge and its exchange in dyadic relationships and the conflicting evidence regarding the role of trust. Trust is described as it relates to the interaction between firms in a dyadic relationship, which we call inter-organizational trust (IOT). Next, three behavioral components inherent in dyadic relationships are introduced and defined using social exchange theory (SET). The chapter concludes by introducing the constructs that this study will investigate.

1.1 Introduction

The source of competitive advantage in knowledge intensive sectors of the economy is the possession of knowledge capital. While knowledge has intrinsic value, there is also economic value in exchange. This exchange can lower the cost of knowledge creation for a firm and accelerate the development of new indigenous capabilities. Even firms operating in mature markets are becoming increasingly knowledge intensive to differentiate themselves from their competitors (Davenport, 2005). Moreover, the trend toward flatter organizational structures and outsourced competencies (Hammer & Champy, 2001) has only increased the importance of knowledge exchange to create new organizational capabilities with reduced internal resources.

Knowledge exchange behavior (KEB) in a supply channel dyad is determined by individual decision makers held accountable for the results that their organization achieve as a consequence of the exchange. Thus, as an agent whose personal interest is affected by the results of KEB, the individual assumes the risk of a proposed exchange. Knowledge, in the very cost of its creation, is an investment which is exchanged under risk (e.g. opportunism, misappropriation, etc.) to create enhanced value.

Various economic and social conditions influence when or how KEB can occur. Trust has widely been posited to be an antecedent to knowledge behavior. However, the results in the literature have been conflicting (Liang, Liu, & Wu, 2008). While trust can make knowledge transfer less costly for the receiver (Zaheer, McEvily, & Perrone, 1998) and may facilitate the sharing of certain types of knowledge (Modi & Mabert, 2007) this finding is not universal. For example, Bakker et al (2006) found that knowledge transfer was not contingent on high trust but rather on team tenure. They argued that simply the absence of mistrust was sufficient when there were other more influential factors that motivated the formation of the relationship. Moreover, they argued that it was relationship tenure which facilitated enhanced knowledge sharing. Watson & Hewett (2006) found a negative correlation between trust and knowledge contribution to a knowledge management system. Curiously, they also found trust and employee tenure to be negatively correlated; however, this was not one of their hypothesis. Chao - Min Chiu & Wang (2006) found trust to not be positively associated with knowledge sharing. They speculate that knowledge sharing (virtual communities was the context of their research) is driven by frequent interaction and an expectation of reciprocity even in the absence of trust. Likewise, at the firm level, Kim, Umanath, Kim, Ahrens & Kim (2012) found knowledge exchange to be negatively correlated with high trust when knowledge complementarity was high, a finding diametrically opposite to their hypothesized expectation.

What can explain these contradictory findings, especially the unanticipated lack of explanatory power of trust? Trust - or at least the lack of extreme mistrust - may be a necessary but not sufficient condition for knowledge exchange behavior. In this work, the term *inter-organizational trust* (IOT) will be used to describe the trust state between two organizations. We will use the definition of trust articulated by Mayer, Davis & Schoorman (1995) and empirically validated by McKnight, Choudhury & Kacmar (2002). This conceptualization was found to be robust across levels of analysis (Schoorman, Mayer & Davis, 2007) and underpins our definition of inter-organizational trust. Using the idea of inter-organizational trust, the interaction between firms is relationally neutral or, as Lindenburg (2000) clarified, is based on calculated risk. Additionally, there are contingencies that influence the relationship between inter-organizational trust and KEB. Colloquially, this would be an 'it depends' type answer (Umanath, 2003; Venkatraman, 1989). This research is motivated by the desire to model some of these contingencies with a view to reconcile the contradictory findings of prior research. Thus, our research questions are:

R1: What is the role of inter-organizational trust in knowledge exchange behavior?

R2: What contingencies mediate/moderate impact of inter-organizational trust on knowledge exchange behavior?

1.2 Motivation

If one takes a broader perspective beyond the business literature as suggested by Ahlstrom, Lamond, & Ding (2009), one can find examples of even mistrustful partners (adversaries) exchanging information. For example, during the cold war the Soviet Union and the United States routinely engaged in arms control negotiations that required the exchange of sensitive information on force structures and dispositions. The motivations were unrelated to trust - but of supreme national interest - which compelled knowledge sharing (Suvorov, 1984). This does not mean that inter-organizational trust cannot promote KEB, its role may simply be exaggerated (Bakker, et al., 2006).

Rather than KEB having a single antecedent, viz., inter-organizational trust, we posit that KEB exists in a 'world' or ecology of factors. Figure 1.1 is a concept map showing entities which we believe are part of the world in which KEB occurs. This is not a causal or research model but rather an ecology of constructs that are present and help define the environment within which KEB occurs.

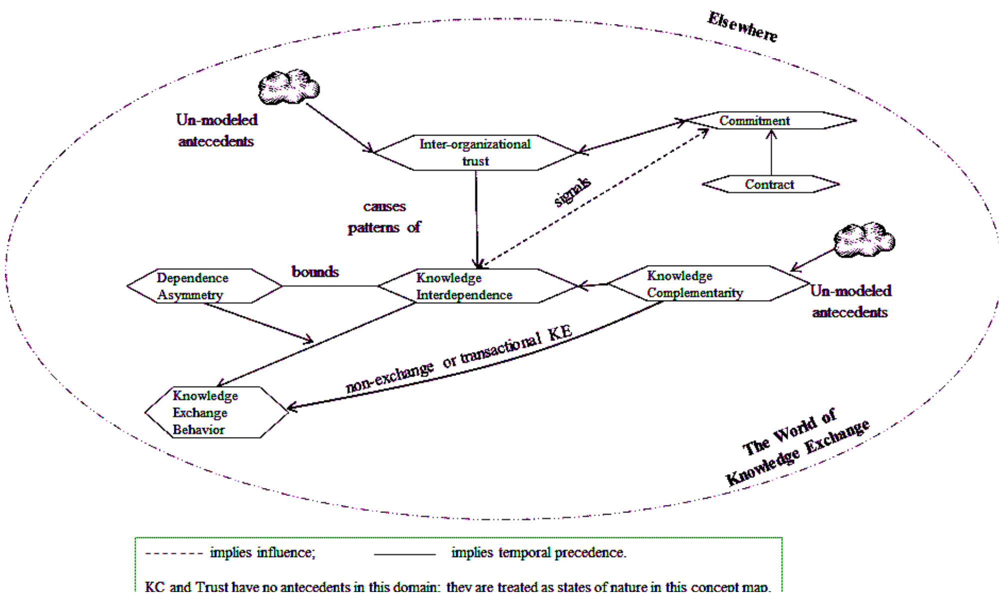


Figure 1.1: Concept Map

In this paper a distinction is made amongst data, information and knowledge because each represents a different level of organizational investment and has an influence on the nature of the supply channel exchange. While recognizing the broad scope of possible definitions, we take the definitions offered by Umanath & Scamell (2007) where *data* is viewed as raw material - unorganized facts about things, events, activities and transactions; data is declarative. *Information* is data in context, data organized within a framework that has meaning to a user (Umanath & Scamell, 2007). *Knowledge* can be characterized as 'know-how' developed from the assimilation of information and has a higher semantic value than information. The distinction between information and knowledge may sometimes be blurry; in fact, it may at times be judgmental. Nevertheless, the characteristics of the exchange, including antecedent conditions and contingencies, are not fundamentally altered. The object of the exchange, viz., information or knowledge, has economic value to the dyad above and beyond routine transactional data and is of a strategic nature.

While the technological means of *how* knowledge transfer occurs in a supply channel have been studied (e.g. Kim & Umanath, 2005; Kim, Umanath & Kim, 2006), the focus of our research is under what conditions it occurs. Sharing knowledge requires a higher inter-organizational commitment than electronic information transfer (EIT) because of the inherently higher value of knowledge (Dyer & Singh, 1998).

To address the gap in the literature we use both game theory (e.g. Harrington, 2008; Schelling, 1960) and social exchange theory (Blaue, 1964, Kelley & Thibault, 1973, Thibault & Kelley, 1959) to model the interdependent decision making associated with KEB in a dyad. We investigate how KEB is promoted or attenuated based on a perceptions of cost (risk) compared to reward. Whether the payoff associated with KEB is positive or negative depends on, among other things, inter-organizational trust, *knowledge complementarity* (KC), *knowledge interdependence* which together will determine whether the benefits of KEB outweigh the risks for each member in the dyad. Specifically, we conceptualize the relationship between inter-organizational trust and KEB as moderated by knowledge interdependence and KC. Since prior empirical evidence (Kim, Umanath, Kim, Ahrens & Kim, 2012) supports our conceptual premise that low levels of KC entails insignificant KEB, we examine our research model exclusively in the context of high KC.

Then, we use an extension of social exchange theory (SET) (Blau, 1964; Thibault & Kelley, 1959), sometimes referred to as the *theory of interdependence* (Kelley & Thibaut, 1978; Wickham & Knee, 2012), to analyze the patterns of interdependence in the payoff structure of the game theoretic model for characterizing the behavioral motivations behind KEB. We will use the term SET in this work to refer to both the social exchange theory and its extension, the theory of interdependence.

2. Literature Review

"And oftentimes, to win us to our harm, the instruments of darkness tell us truths, win us with honest trifles, to betray['s] in deepest consequence." --Banquo, Act I, scene iii MacBeth

While empirical evidence suggests that trust can promote knowledge exchange behavior (e.g. Andrews, Preece & Turoff,2002; Bromiley & Cummings, 1995; Davenport & Prusak,1998; Dwyer, Schurr & Oh,1987; Klein & Rai, 2009; McEvily & Zaheer, 1999; Nahapiet & Ghoshal, 1998; Nonaka, 1994; Ridings, Gefen & Arinze, 2002; Thorelli, 1986), this research is interested in cases where trust may have an ambiguous or limited role. Thus, while acknowledging the broad literature base supporting the role of trust in knowledge exchange, we limit our attention to research findings where the role of trust on knowledge exchange is equivocal - the gap which this research aims to address.

2.1 Contradictory findings of trust

A meta-study of 23 peer reviewed journal articles and five conference proceedings show that the results in the literature have been conflicting (Liang, Liu, & Wu, 2008) . The object of their study was to evaluate the role of the following antecedents on knowledge sharing: perceived benefit, organizational commitment, social interaction, trust, and organizational support and reward systems. Most related to the object of this research was their hypothesis H1d: Trust is positively associated with an individual's knowledge-sharing behavior.

Of the 14 papers included in this meta-study that directly related to this specific hypothesis nine studies showed significant positive influences on individuals' knowledge-sharing behavior; but five other studies did not agree with this finding. The range of correlations between trust and knowledge sharing behavior was .04 to .600. The broad range of correlations suggests that trust can have an effect on knowledge exchange behavior ranging from weak to dominant.

In fact, Bakker, Gabbay, Kratzer & Engelen (2006) argue that '… trust is highly overrated as a driver of knowledge sharing.' Their study sought to determine alternatives to the role of trust in knowledge sharing. Using social capital as the primary conceptual basis, they studied 23 new product development projects consisting of 91 individuals using a field survey. This survey has measures for trust derived from (Mayer et al, 1995) and included competence, benevolence and integrity. Non-trust items included team size, tenure and education.

Bakker et al (2006) found that the effect of trust on knowledge exchange behavior was "…negative: it seems that members with much trust in the capability of others tend to share less know-how with them as they expect highly capable others to already possess the know-how." They conclude by arguing that trust is not an end in itself but rather a consequence. Rather team tenure and a history of past successful collaboration is a more important driver of knowledge sharing behavior.

This is not to suggest that the role of trust in knowledge sharing has been refuted. In fact, Chiu, Hsu & Wang (2006) found that it can. Their work studied virtual communities using the social capital perspective and employed a field survey of users of a professional virtual community using trust items found in the extant literature. The dependant variables were the quantity and quality of knowledge shared in the communities. The independent variables included: social interaction ties, trust, norm of reciprocity, identification, shared language and shared vision.

Of interest to this research were the hypotheses relating to trust:

H4a. Trust is positively associated with the *quantity* of knowledge sharing.

H4b. Trust is positively associated with the *quality* of knowledge shared by members

They found that the trust of a member in a virtual community (VC) was significantly and positively correlated with the quality of the knowledge (H4b) that a member shared ($r=.18$, $p<.05$). However, this finding was overshadowed by the fact that high trust was *not* significantly associated with an increase in the *quantity* (H4a) of knowledge shared.

In discussing the apparent weak role of trust in facilitating knowledge sharing in a VC the authors concluded that there were two possibilities. First, the effect of close and frequent interaction may be more important for sharing in a VC than trust itself - similar to the findings in Bakker et al (2006). Or, that trust is simply less important in environments that are perceived to be less risky. While not part of this study, the latter possibility appears to suggest institution-based trust as described in McKnight, Choudhury & Kacmar (2002). *Institution-based trust* is based on the structural characteristics of the environment and unrelated to an individual partner(s). Frequent and close interactions amongst members in a VC could create a sense of trust based on the structural characteristics of the forum.

While the impact of trust on knowledge sharing may be weak as found in the previous study, it can also be negative as Watson & Hewett (2006) found in a study of knowledge management systems (KMS). This study had two aims regarding KMS usage: (1) the willingness of individuals to contribute their knowledge to the system and (2) the rate at which individuals access and reuse knowledge within the system.

This research used social exchange theory and expectancy theory to derive hypothesizes relating to the contributions to and use of KMS. Data was collected using a survey of 900 employees (48% response) in a large division of a firm and included employees who used the KMS for the creation or reuse of knowledge.

Their hypothesis "H8: Trust in knowledge source will be positively related to the frequency of knowledge reuse" was supported ($r=.16$, $p<.01$). Pertinent to this research, but not one of the hypotheses in the study, was the effect of trust on knowledge contribution. The correlation was found to be insignificant; that is, there is *no* relationship between trust in a KMS and contribution to it. This suggests that if users trust a system they will use it but not necessarily contribute their own knowledge to it.

This study also found that trust in the system and team tenure are negatively correlated ($r= -.11$, $p<.05$). The authors speculate that the longer tenured respondents may not have as much training – and trust – in the system as newer employees. A possibility not discussed by the authors, however, is that longer-tenured employees may have 'more history' with the system and have developed reasons to have less trust. This is speculative since the study did not detail this aspect of the employee base in the focal firm.

Other results from this study, that were not hypothesized but are of interest, include the finding that trust in the system is not correlated with advancement in the firm but was with job performance ($r=.22$, $p<.001$). Basically, if one trusts the system at this firm, they won't get ahead in their careers but they will be better in their jobs.

An alternative, albeit indirect, approach to understanding the effects of trust on knowledge sharing is to consider the antecedents and contingencies of trust itself. For example, Ferrin & Dirks (2003) studied the mediated effects of reward structure on trust. Two types of reward systems were considered:cooperative and competitive. A cooperative reward is based on joint outcomes in contrast to competitive rewards for individual performance. The effect of these two reward systems on trust was mediated by: partner information sharing, partner's lying, perceived motives, own information sharing, own lying and perceived performance [of the partnership]. Initial trust and performance were modeled to act on trust without mediation.

This study used a lab-based experiment where 224 upper division business students were randomly assigned to a computer terminal which allowed them to interact with an anonymous partner forming a dyad. Each dyad was randomly assigned to a low or high trust condition and then to a cooperative, mixed, or competitive reward condition. The dyad was given a simulated survival task called 'Moon' or 'Wilderness' - scenarios requiring the members of the dyad to supply or withhold knowledge to promote their own and/or their partner's survival based on the scenario information in the simulation.

For our purpose we consider a subset of their research model depicted in Figure 2.1 showing the path coefficients (correlations) between both reward constructs mediated by 'own information sharing. The other mediators (e.g. own lying) were omitted since these constructs don't directly relate to the object of the current research. The construct 'own information sharing' has a direct analog in this research as a member of a supply channel dyad contributing knowledge.

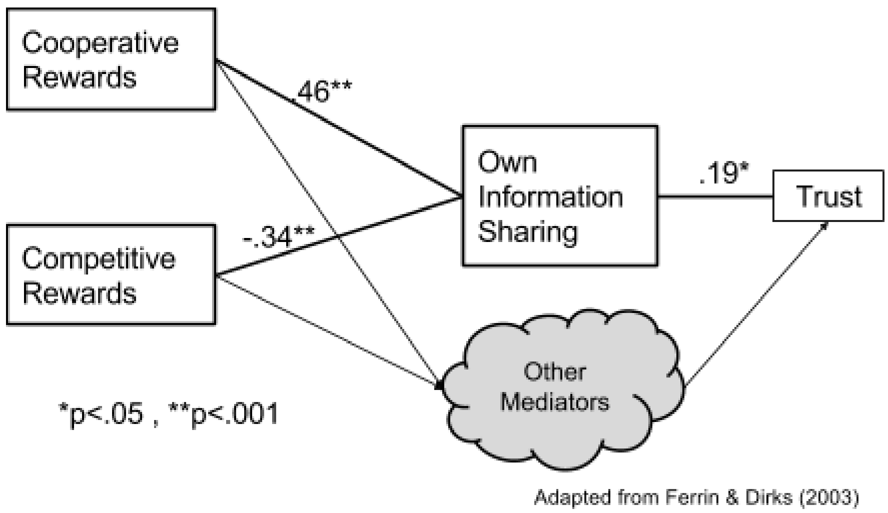


Figure 2.1: Research Model for Ferrin & Dirks (2003)

It is outside the scope of the current research to unpack trust or investigate its sources as this study does. Nevertheless, the relationships between reward and information sharing when compared with information sharing and trust, as shown in the figure, do have implications for the current research. It can be seen that the relationship between knowledge sharing and rewards is much stronger than information sharing and trust which would seem to bolster Bakker et al (2006) assertion that the importance of trust on knowledge sharing is overstated.

In other contexts, trust may be indistinguishable from similar, yet distinct, constructs. For example an exploratory study by Ding, Ng & Cai (2007) sought to identify the personal constructs present which influenced a team member's willingness to share knowledge with a design team and also a members perception of trust of other members of the team.

In this study data was collected from nine architectural design team members in three major Chinese cities using structured interviews relating to an individual member's interaction with their design teams. Seven interviews focused on a member's perception of trust toward team members while two focused on the willingness to share knowledge. The participant responses were then coded into categories which were then analyzed using hierarchical cluster analysis and principal component analysis (PCA) to elicit distinct groupings (i.e. factors that could be identified as constructs).

From the response data, four factors were extracted and labeled as: a team member's attitude to work, ability, personality and social interaction. Trust was not explicitly identified in any of the extracted factors. While the analysis was exploratory in nature - cluster analysis, PCA and content analysis - the lack of any factor with ‘trust-like’ characteristics would seem to suggest the possibility that trust could appear similar to other factors in certain contexts as Ding et al (2007) noted.

The effect of trust on knowledge sharing need not be dichotomous (yes/no) but may be contextual as Ding et al (2007) observed or contingency based as suggested in Kim et al (2012). In spite of this, there is a scarcity of research investigating under what conditions trust really matters. Rather, trust is typically included as merely another potential antecedent. However, another meta-study by Witherspoon, Bergner, Cockrell & Stone (2012), like the meta-study by Liang et al (2008) previously discussed, present a panopticon on trust and knowledge sharing.

Witherspoon et al (2012) investigated antecedents of knowledge sharing by reviewing 46 studies and dividing them into three categories relating to: knowledge sharer’s intention and attitude, reward structure and organizational culture. This was accomplished by using a keyword search of academic publication databases (EBSCO, Web of Science, Google Scholar, ABI Inform and SSRN) yielding approximately 8,900 published journal articles from over 17 disciplines spanning business, economics, engineering, philosophy and social work among others (the provided list was a summary). From this initial sample, studies were excluded if they were not relevant, had no or inappropriate statistics for meta-analysis, not in English or unable to retrieve article. The final sample consisted of 46 journal articles.

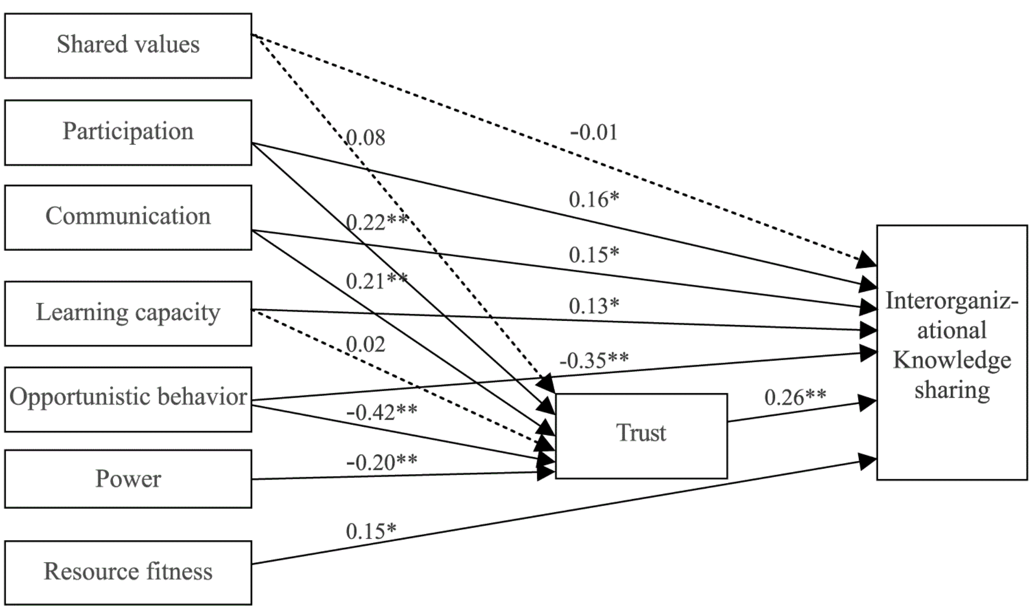
The focus of this meta-study was on knowledge sharing *behavior* and knowledge sharing *intention* and their associated antecedents. This study grouped the antecedents of both (common to both consequents) into three categories:intentions/attitudes, organizational culture and rewards to knowledge sharing. Of interest to the current research is their hypothesis H2d relating to KS behavior; 'Social trust is positively associated with KS' which was supported ($r=.287$, $p<.01$).

It should be noted though that the effect of trust on KS was the 3rd lowest of the nine organizational culture items used (e.g. organizational support-KS, $r=.463$, $p<.01$). Additionally, the relationship between trust and KS behavior was found to be moderated by culture (collectivist or individualist).

As the previous research has shown, the effect of trust on knowledge sharing behavior can be contingency based and not the dominant driver of knowledge exchange. This is bolstered by other research showing that the antecedents of trust can also be the same as knowledge sharing behavior itself (Cheng, Yeh & Tu, 2008).

Cheng, Yeh & Tu (2008) investigated how trust interacts with factors affecting interorganizational knowledge in green supply chains where partners have conflicting incentives to compete and cooperate. Data was collected by administering a survey to respondents at 397 major green manufacturing firms in Taiwan using items for nine constructs derived from the literature (see cited work for details of the constructs and instrument). This resulted in a response rate of 72.5 percent for 288 effective responses.

Structural equation modelling (SEM) was used to calculate the path coefficients (the hypothesized relationships) between the antecedents, mediators and the consequent (inter-organizational knowledge sharing). The research model with results is shown in Figure 2.2 (Cheng et al, 2008)



Note: * and ** denote significance at $p < 0.05$ and $p < 0.01$ respectively

From Cheng, Yeh & Tu (2008)

Figure 2.2: Research Model for Cheng et al

Based on these results, Cheng et al (2008) argue that trust does have a positive influence on knowledge sharing because "constructs with a significant influence on trust positively (such as participation and communication) or negatively (such as opportunistic behavior) also have a corresponding influence on knowledge sharing." (Cheng et al, 2008). In effect, they are suggesting that trust mediates the relationship between the antecedents of trust which also have a direct (unmediated) relationship with knowledge sharing. This result demonstrates that knowledge sharing and trust can share the same antecedents and may provide insight into the ambiguous role of trust on knowledge sharing found in other research.

Much of the discourse on the role of trust on knowledge exchange does not differentiate between receiving or contributing knowledge. This may be an oversimplification since knowledge *exchange* can consist of both contributing and receiving knowledge - as this dissertation research will explore. Trust may have a different effect on contributing knowledge vs. receiving knowledge as indeed Faraj & Wasko (2010/14) have shown.

In their research Faraj & Wasko (2010/14) studied knowledge sharing behavior on three technical computer-related newsgroups by collecting 14,196 postings over a 50 day period. From this, 4,879 distinct users were identified and sent an online survey via email. A total of 1,023 usable responses (24% response rate) was generated. The survey consisted of items in five groupings: motivation, ability, relational capital, knowledge exchange behavior and the control variables. Knowledge exchange behavior is the focal phenomena and the survey included items relating to both a member's contribution to the forum as well as its acquisition of knowledge from the forum.

The effect of social capital on knowledge exchange is represented by three constructs that were found from a factor analysis of the responses to the survey items: motivation, ability and relational capital. The construct for motivation represents a member's professional and social affiliation (e.g. IT professionals). Ability is defined as job subject matter competence (programming) and tenure. Relational capital is characterized as obligation, norms, identification and trust.

While the role of trust on knowledge exchange behavior is one of the research questions in the current research, Faraj & Wasko (2007) define their hypothesis at a more general level - the groupings of constructs previously described. Of interest to the current research is the following hypothesis because it derives from the same theoretical lenses as the current research uses:

H1a – Social affiliation will have a positive relationship with knowledge acquisition.

The findings were significant, but opposite, to the hypothesized relationship.

Social affiliation was defined in this research (Faraj & Wasko, 2007) to include: to gain a feeling of belonging, to meet new and different people, be socially competent and skillful and build friendships with others. This finding will be further explored in the current research.

H1b – Social affiliation will have a positive relationship with knowledge contribution.
Not supported.

H4a – Longer individual tenure in the group will have a positive relationship with knowledge acquisition. (supported)

H4b - Longer individual tenure in the group will have a positive relationship with knowledge contribution. (supported).

It was also found that trust and obligation - constructs from the social capital perspective- support knowledge exchange behavior in different ways. If a member had a sense of obligation to the group they would *contribute* knowledge without necessarily trusting the other members. However, members *acquiring* knowledge appear to trust the other members in the community yet do not feel obligated to contribute.

Kim, et al. (2012) found empirical evidence for a surprising discovery that despite high knowledge complementarity and high inter-organizational trust, knowledge sharing can be retarded in a supply channel engagement. In the *post hoc* reflection of this unexpected empirical finding they found literature support (Palmatier, et al. 2007) for a conceptual argument that perhaps knowledge interdependence operated as the contingency leading to their empirical finding. They posit that presence of significant interdependence in a supply channel engagement may even preclude the need for inter-organizational trust; the supply channel partners may have no choice but to share knowledge due to interdependence despite absence of inter-organizational trust or even prevalence of mistrust. By not sharing knowledge, the partners may face a slight risk of failure, a risk perhaps insignificant compared to the risk of dealing with the expected damage due to the opportunistic behavior of an untrustworthy partner. This unexpected finding by Kim, et al. (2012) served as the very motivation for the current research. The first hypothesis of this dissertation is focused squarely on unraveling the mystery behind this finding.

2.2 Concluding remarks about trust in the literature

This literature review does not purport to be an exhaustive survey of the literature on the relationship between trust and knowledge exchange behavior. The literature base is immense and deep and a study could be made just on the state of the research on this topic (e.g. Liang et al , 2008).

Instead, the intention of this review is to identify research findings that were contrary to the prevailing popular view that trust perhaps always positively influences knowledge exchange. Indeed, there are conditions where this relationship breaks down. The research reported in this dissertation is triggered by the intention to explore the contingencies capable of explicating the conditions under which trust can promote or retard knowledge exchange behavior.

3. Theory and Constructs

In this section, the roles of game theory and relational view (Dyer & Singh, 1998) as complementing theoretical perspectives to assess knowledge exchange behavior are presented. Social capital theory is employed to reinforce the relational perspective. In addition, theory of interdependence (a subset of social exchange theory) is used as a complement to determine the incentive structure for the game-theoretic engagement.

Next, game theory and the relational view are juxtaposed as alternative bases to establish the foundation for the ensuing hypotheses. Finally, the constructs of interest are elaborated in the context of these theoretical perspectives and the hypotheses are developed.

3.1 Theoretical Foundation: Game Theoretic versus Relational Approach

Our basic premise in this research is that supply chain channels entail on-going dyadic relationships of indefinite durations. Market purchase of knowledge, as in consulting relationships may be characterized as an intermittent phenomenon with no specific need for an on-going relationship or reciprocal exchange of knowledge.

Efficient and effective transfer of data and information can occur via market transactions or through hierarchical governance structures (Williamson, 1985). However, inter-organizational phenomenon such as knowledge exchange behavior in a supply chain channel often require reciprocal patterns of behavior, and may be better served by relational/network forms of organizations less guided by a formal structure of authority and more driven by reciprocity, collaboration, etc. The context of our research, viz., supply chain channel, may fit the mold of a relational/network structure involving knowledge complementarity, reciprocity, collaboration, inter-organizational trust, long-term interaction, etc. Since game theory can deal with dyadic (and larger) interactions, it is well suited to study supply channel interactions. Likewise, the relational view of inter-organizational engagements is another viable theoretical basis for studying knowledge exchange behavior in a supply channel context.

The focal unit in this research is the supply channel dyad and the relational view and game theory are used to predict knowledge exchange behavior in the dyad. However, the dyad consists of individual members who have a distinct identity – motivations, incentives, dependence, etc. While it is possible to restrict attention to the dyad level, this research goes further to include member-specific considerations. This is because the dyadic response is powerfully influenced by member-level considerations. Thus, the primary theoretical bases (relational view and game theory) are augmented by social exchange theory and the social capital perspective to broaden the perspective for considering the effects of the dyad on its individual members.

Let us use a simple supply channel context to facilitate the explication of the theoretical background. Two firms, say A and B, in a supply channel engagement will have to make a strategic decision – to “Share” or “Not share” critical proprietary knowledge with its partner based on the respective payoff structures. A crucial assumption in this scenario is that the supply channel partners know each other’s payoff structure in addition to their own (the common knowledge assumption). The following sections articulate the theoretical rationale that is expected to lead A and B to their respective strategic decision - to “Share” (KE+) or “Not share” (KE-) critical proprietary knowledge.

3.1.1 Game theory in brief

Game theory models interdependent choices driven by strategic behavior where an individual actor’s outcome depends on the choices made by others (Myerson, 1991). More formally, game theory is the study of the ways in which strategic interactions among economic agents produce outcomes with respect to the utilities (i.e., preferences) of those agents where the outcome in question might have been intended by none of the agents (Stanford Encyclopedia of Philosophy). The latter definition clarifies that the unit of analysis can be either an individual or a group (unit). A game consists of a set of players (or actors), a set of moves (strategies) available to those players and a specification of payoffs for each combination of strategies.

A game can be represented primarily in three ways: (1) characteristic form, (2) extensive form and (3) normal form. The characteristic form is an analytical representation of a game modeling interaction of two or more entities. Since our focal unit is a dyad, this representation offers little additional insight when compared to the other two alternatives. In its stead, we use the normal form of the game (sometimes also called strategic form) which is a compact matrix representation of the actors, the available strategies and the associated payoffs. A brief description of extensive form games is included in Appendix E. For a more detailed coverage, please see Harrington (2008).

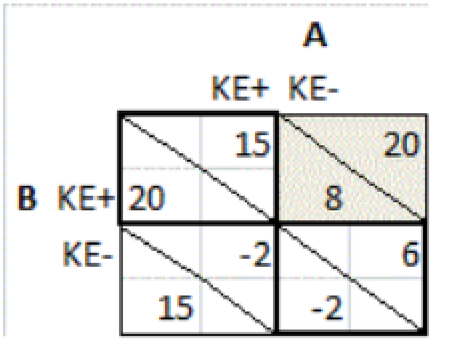


Figure 3.1: a Normal Form Game

An example for a normal form representation of a game is shown in Figure 3.1. In the game shown, there are two actors – row (**B)** and column (**A)** – each of which has two strategy choices. A *strategy* is fully specified decision logic for each actor where a response is conditioned on what it expects its partner to do.

Game theory is predicated on the 'economic person' metaphor where an actor is: (1) rational and (2) seeks individual payoff maximization. The four cells represent the payoff for each actor for each possible strategy pair. The best payoff for both A (Column) and B (Row) is [20] while the worst payoff for both is [-2]. But then, their payoffs are not determined by their own respective behavior alone; it is clearly contingent upon the partner's action. For example, B's best payoff of [20] is achievable not just when it selects KE+ but only if A also selects KE+. The game-theoretic perspective described above clarifies that, knowing A's payoff structure, B cannot expect A to 'share' knowledge (KE+) since 'not share' is a better strategic option for A if B chooses KE+. Choosing the second best payoff [15] of KE- is, unfortunately, not a *safe* option for B, since B cannot expect A to run the risk of getting its worst payoff of [-2] by selecting KE+. From A's (Column) perspective, KE- (not sharing knowledge) is the ***least risky*** choice that has the potential to yield the highest payoff of [20]. In sum, knowing B's payoff structure and also knowing that B knows it's (A's) own payoff structure, from a game-theoretic perspective, A can expect B to choose KE+. B, knowing the same facts about the payoff matrix will have to concede to a lower payoff [8] in order to avoid the worst payoff [-2]. Thus, the supply channel partners end up at the top right cell of the payoff matrix – i.e., B sharing knowledge (KE+) and A not sharing knowledge (KE-). This solution is called the *Nash equilibrium* or saddle point as indicated by the shaded cell. It is a solution predicated purely on individual incentives – a game-theoretic solution.

This solution is, clearly, deficient for row (B) because the equilibrium results in it getting its second worst outcome [8]. Since the payoffs are known to both actors, the nature of the solution – in this case deficient for one – has behavioral implications; the very subject of this research. The other three cells are unattainable if both actors seek an individual maximizing solution. Figure 3.2 illustrates the resulting decision choices.

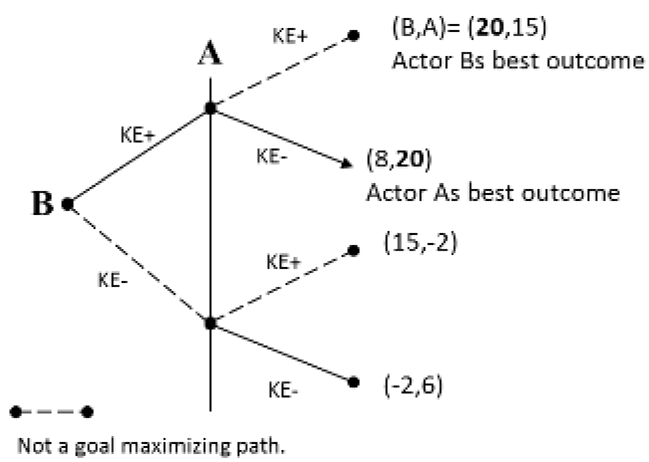


Figure 3.2: A Decision Logic Tree

Row (B) would never choose KE- because it can never get its best payoff no matter what column (A) does. The dashed lines indicate a path that is not payoff maximizing for that actor. Thus, column would not have to make a choice resulting in a payoff of [-2] or [6] which also happens to be to its interest. But if row irrationally chooses KE-, column choosing KE- yields the available outcome of [6] which is at least better than its worst outcome of [-2] – the KE+ choice by A (the column). Being rational, row would select KE+ since there is a path leading to its best outcome of [20]. However, column would still choose KE- to get its best outcome [20]. Since column would always choose KE- that strategy is *dominant* for the column. Additionally, row knows that it could never get at least its second best outcome [15] by choosing KE- because column would still choose KE- resulting in row getting its worst outcome. Thus, row chooses KE+ to definitely avoid its worst payoff - its outcome would be at least [8]. Hence, KE+ is row's *dominant strategy*.

Now, let us examine a second example using the payoff matrix shown in Figure 3.3.

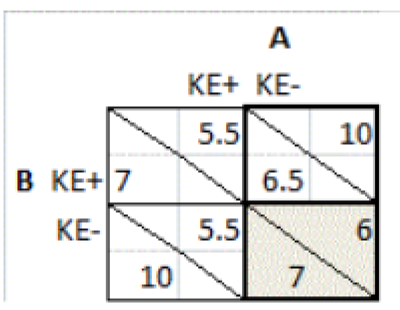


Figure 3.3: A Game with Solution

In this example, the best payoff for both A (Column) and B (Row) is [10] while the worst payoff for row is [6.5] and the worst payoff for column is [5.5]. But then, their payoffs are not determined by their own respective behavior alone; it is clearly contingent upon the partner's action. For example, B's best payoff of [10] is achievable not just when it selects KE- but only if A also selects KE+. The game -theoretic perspective clarifies that, knowing A's payoff structure, B cannot expect A to 'share' knowledge (KE+) since 'not share' is a better strategic option for A no matter what B chooses to do – 'share' or 'not share'. Opting to share knowledge guarantees B its worst payoff. Thus, B's dominant strategy in this situation is KE- (to 'not share' knowledge with A) which provides at least the second best (happens to also be the second worst) payoff for B. From A's (Column) perspective, KE- (not sharing knowledge) is unequivocally the dominant strategy with the potential to yield the highest payoff of [10] while avoiding the possibility of its worst payoff of [5.5]. Choosing to 'share' knowledge with B (KE+) is simply not an option for A since no matter what B does A is guaranteed its worst payoff of [5.5]. In sum, knowing B's payoff structure and also knowing that B knows it's (A's) own payoff structure, from a game-theoretic perspective, A can expect B to choose KE-. B, knowing the same facts about the payoff matrix ought to arrive at a similar expectation of KE-(not share knowledge) from A and will therefore, have to accept a lower payoff [7] in order to avoid its worst payoff [6.5]. Thus, the supply channel partners end up at the bottom right cell of the payoff matrix – i.e., both A and B not sharing knowledge (KE-). Note that A does not get its best payoff of [10] either; A also has to settle for its second best payoff. This, the shaded cell in the payoff matrix, is the *Nash equilibrium* or saddle point in this case. This is the solution predicated purely on individual incentives – a game-theoretic solution.

In the two examples discussed above, the game-theoretic solution does not yield the best payoff for B in either case while A achieved its best payoff in the first case only.

Game-theoretic strategy predicated upon self-interested behavior motivates both the actors to seek the least risky choice that has a potential for a higher payoff should its partner for some reason exhibit irrational behavior. Let us next examine the same two payoff matrices using a different theoretical lens.

3.1.2 Relational View of Dyadic Engagements

The relational view of an inter-organizational engagement (Dyer & Singh, 1998), viewing the engagement as more than a simple engagement – i.e., as a "relationship", seeks to maximize relational rent for the supply channel enabled by the presiding cooperative behavior. Rents in inter-organizational engagements are supernormal profits attainable only in the context of a relationship that facilitates cooperative behavior among the supply channel partners. Dyer & Singh state several ways for generating relational rents. Of direct relevance to our research is their suggestion of combining complementary but scarce resources for generating relational rents.

3.1.2.1 Social capital theory

Thus far, our discussion has been on the dyad level – how partners engage with one another. But there are underlying individual member motivations explaining *why* an actor behaves in the manner prescribed by either game theory or the relational view. The relational view only addresses a collective goal orientation whereas game theory considers only the outcome consequent to individual actor's attempt to maximize its individual payoff. However, as explained by the relational view there are reasons why a member would be willing to forgo an individual payoff maximizing action. Members of a dyad may be attracted to a 'pro-relational' orientation for individual reasons; social capital theory articulates the basis.

Social capital theory (Nahapiet & Ghoshal 1998) reinforces the relational view of an interorganizational relationship since it also addresses the value of 'relationship' in inter-organizational engagements. Naphiet & Ghoshal (1998) define social capital as "…the sum of, the actual and potential resources within, available through, and derived from the network of relationships possessed by an individual or social unit". Social capital has also been described as "…collectively-owned capital, a 'credential' which entitles them to credit" (Bourdieu, 1986). Cooperative behavior underpins the conceptualization of the social capital perspective. Any capital, social or otherwise, is, by definition, capable of generating a yield; the yield from the relationship (social) capital is equivalent to relational rent. The relational rent is the super-additive payoff over and above the sum of the parts. We conceptualize relational rent (the super-additive payoff) as joint payoff in this research.

3.1.2.2 Relational strategy exemplified

Let us now revisit the two games examined earlier through the lens of game theory using the relational view. We saw, in the first game matrix (reproduced in Figure 3.4), that the economic solution (upper left cell) is deficient for one of the actors – actor B (row).

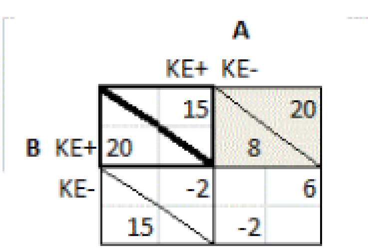


Figure 3.4: A Game with Two Possible Outcomes

If, however there is a shared desire within the dyad to maximize the joint payoff by selecting the upper left cell the engagement can achieve a higher combined return than the self-interested solution (upper right cell). The column actor (A) here incurs a cost to itself – it loses 5 – in order that a surplus (rent) of 7 could be generated for the relationship. However, since the column actor (A) is invested in the relationship, it is entitled to a credit from the rent. The row actor (B) ought to be willing to share the rent generated by the joint-payoff maximization solution in order to encourage column's cooperation towards this strategy – at the same time, expecting to reap a better payoff for itself than the lower selfish solution. How the rent of 7 is appropriated by each member in the dyad is outside the scope of this research. Suffice it to say that column should at least get a sufficient share of this surplus to recover its individual loss by forgoing a selfish solution. Likewise, row would not expect to get a dominant share of the rent because it already fared better than the selfish solution. Thus, both partners stay attracted to a pro-relational posture toward each other.

In the second example shown in Figure 3.5, the economic solution derived via game-theoretic approach is actually deficient for both the actors; neither A or B is able to get its highest individual payoff of [10].

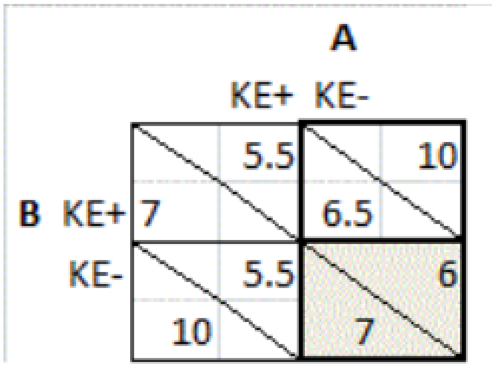


Figure 3.5: A Non-Economic Solution

This is because both the actors are seeking the least risky choice that has the potential for each of them to achieve its highest payoff should its partner for some reason makes the wrong move; hence the deficient outcome for both. However, an opportunity does exist for the dyad to maximize the joint payoff in the engagement which indeed is higher than the sum of the best achievable individual payoff predicated on selfish intentions. The joint payoff-maximizing solution is the upper right cell. This solution generates a rent of 3.5 (joint payoff [16.5] - sum of the deficient individual payoffs [13] resulting from the game-theoretic solution).

The row actor (B) here incurs a cost to itself – it loses .5 – in order that a surplus (rent) of 3.5 could be generated for the relationship. However, since the row actor (B) is invested in the relationship, it is entitled to a credit from the rent. The column actor (A) ought to be willing to share the rent generated by the joint-payoff maximization solution in order to encourage row's cooperation towards this strategy – at the same time, expecting to reap a better payoff for itself than the lower selfish solution. How the 3.5 rent is appropriated by each member in the dyad is outside the scope of this research. Suffice it to say that row should at least get a sufficient share of this surplus to recover its individual loss by forgoing a selfish solution. Likewise, column would also expect to get some share of the rent to gain an incremental payoff above the selfish solution. Thus, both partners stay attracted to a pro-relational posture toward each other.

Each member is influenced by its association with the dyad - specifically, how much independence it can exercise, how susceptible it is to its partner's behavior and the need (or lack thereof) to coordinate its actions with this partner. These perceptions are both a result and antecedent of how a member interacts with its partner – pro-relational or self-interested. These behavioral implications have definitions at both a member and dyad level. Social exchange theory aptly captures these definitions.

3.1.3 Juxtaposing game theoretic and relational perspectives

The conditions steering the supply channel partners towards a game-theoretic or relational strategy in their knowledge exchange behavior (KEB) are exogenous to the two strategies.

Knowledge complementarity (KC) and trust, in this case, inter-organizational trust (IOT), have been proposed and examined by prior research based on sound theoretical foundations as major exogeneous factors influencing KEB in dyadic engagements. Since prior research is reasonably conclusive about absence of KEB when KC is low, the focus of this research is aimed specifically at a high KC environment.

The role of trust on exchange behavior, be it data, information or knowledge, profusely studied by prior research, has yielded conflicting and inconclusive findings as reported earlier in the literature review. The aim of the research is not to add another data point to the inconclusiveness in the findings; rather, the focus is geared towards an attempt to clarify as to when and how trust promotes or retards KEB and when/how trust may be irrelevant. When Kim, et. al. (2012) recently found that with increase in trust in a dyad KEB was retarded, they speculated with literature support that knowledge interdependence between the participants in the dyad as a highly viable contingency capable of clarifying the conditions under which impact of trust on KEB may be promoted, retarded or be of no consequence. This research is anchored precisely at this position.

Briefly, the thesis of this research is that in high trust conditions, a supply channel dyad seeks maximization of joint-payoff, while low trust conditions tend to steer the dyad members towards self-interested behavior - theorized by relational view and game theory respectively. Interestingly, such a propensity by the dyad need not necessarily mean that low trust retards KEB and high trust promotes KEB. Game-theoretic solution generally sought in low trust environments can sometimes promote KEB simply because sharing knowledge may indeed best serve the self interest of the partners of the dyad. Likewise, joint-payoff maximization can occur when the members of a dyad do not share knowledge (retard KEB) even when the trust in the dyad is high. At times, the game-theoretic strategy and relational strategy may lead to the same solution essentially rendering trust irrelevant. This research seeks to find out if a key ingredient facilitating these different behaviors which seem to defy conventional wisdom, is knowledge interdependence.

3.1.4 *Role of the theory of interdependence*

The theory of Interdependence (TID) is often construed as a subset of a larger scale of social exchange theories and was first introduced by Kelley and Thibaut in 1959 and was formalized by them as a theory in 1978. Social exchange theory (SET) proposes that social behavior is the result of an exchange process and examines how people exchange rewards and costs in a relationship. SET states that there are rewards and costs to any relationship and that people try to maximize the rewards while minimizing the costs (Blau, 1964).

The theory of interdependence extends this inquiry by articulating as to how peoples' expectations of interpersonal relationship are mediated by balancing rewards against costs. The actors in a dyad evaluate the payoff of a relationship against the available alternatives; if there are better alternatives or the costs outweigh the rewards, one or both members of the dyad will prefer to terminate or abandon that relationship (Kelley and Thibaut, 1978). Cost-benefit analysis and comparison of alternative are the building blocks of TID.

As is, the unit of analysis in social exchange theories (including theory of interdependence) is the individual. In the supply channel context, we are extending the concepts of TID to the organizational unit level. The adaptability of the theory to the organizational unit level is justified on the basis of homogeneity in purpose of an organizational unit. This allows us to consider two organizational units in a supply channel to be represented by individuals who are acting as agents on behalf of their firm. Therefore, presuming the absence of egregious goal incongruence within the unit, we use social exchange theory as a theoretical lens to characterize group behavior. We use TID for the conceptualization of interdependence as well as for the development of patterns of interdependence which influence behavior. The complementing role of TID is further elaborated after the constructs have been explicated in section 3.2.

3.1.5 *The research approach in a nutshell*

The focal phenomena of this research – knowledge exchange behavior in a supply channel dyad – span two levels of analysis (Figure 3.6). The hypothesized relations are for a dyadic level of analysis and are characterized using the relational view or game theory. These two perspectives offer complementing but possibly contradictory conclusions. At a deeper level, however, the behavior of the dyad is influenced by its constituent member's individual motivations. The individual/member level inquiry is aimed at gaining insights beyond the hypothesized dyad level effects.

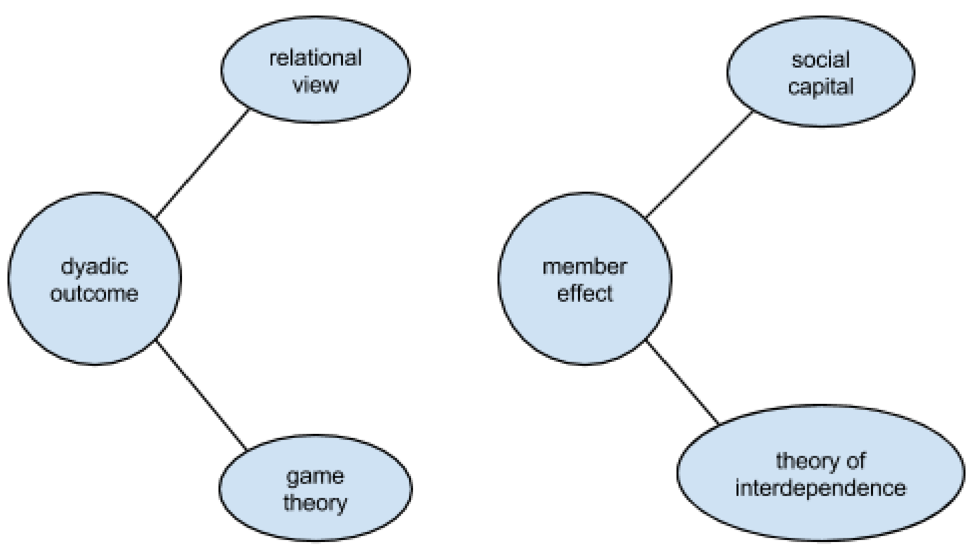


Figure 3.6: Conceptual Basis

This research aims to study knowledge exchange behavior at both the dyad and member level of analysis using the four conceptual bases described (game theory, relational view, social capital and the theory of interdependence) as shown in Figures 3.6 and 3.7. Thus, the realm of this study is partitioned by the level of analysis. In addition, the role of trust between firms and its effect on knowledge exchange behavior in the supply channel is treated as a second partition.

There are two dimensions which define this study at the most basic level: (1) orientation and (2) level of analysis. A member in a dyad may have a pro-relational or self-interested orientation as portrayed in the horizontal axis. The effects of knowledge exchange behavior are interpretable at both the hypothesized dyad level and at the individual member level as captured through the vertical axis.

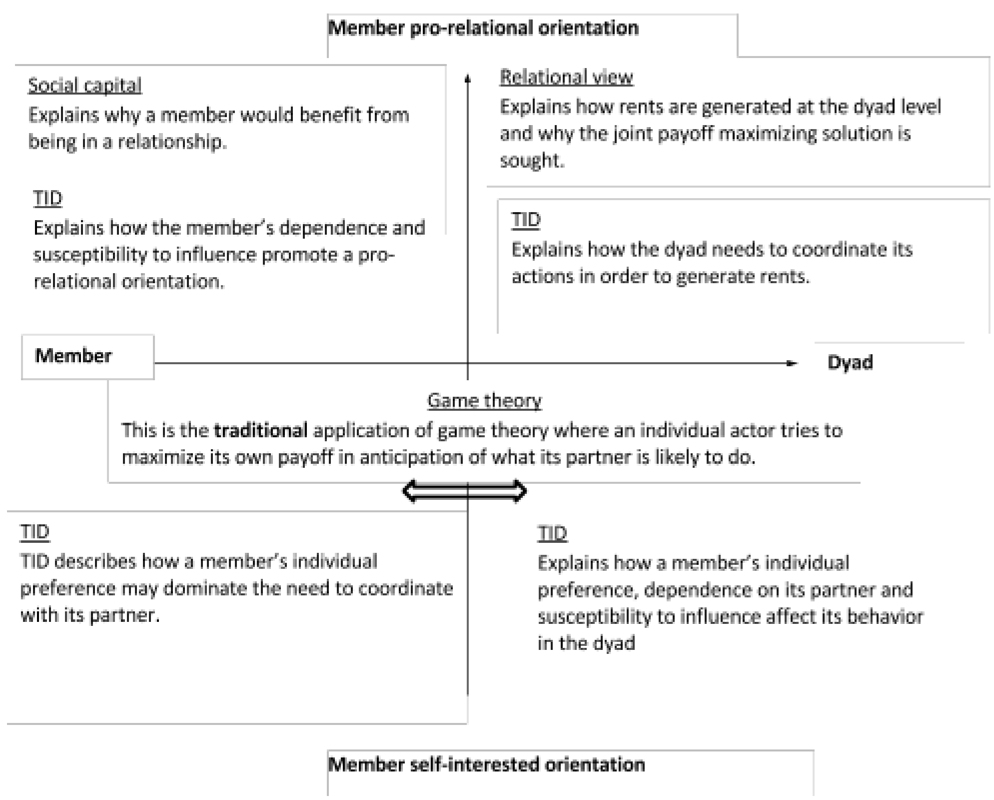


Figure 3.7: Theoretical Basis

3.2 Constructs

The constructs identified in the motivation section – knowledge complementarity, interdependence[1], knowledge exchange behavior and inter-organization trust – need to be defined in the context of the theoretical background articulated in Section 3.1. Specifically, the constructs of knowledge complementarity and interdependence will be represented within 2 x 2 matrixes which represent two actors in a dyadic relationship with two actions available – to exchange knowledge or not. This allows individual actor's actions to be predicted (e.g. equilibrium conditions) using game theory. The *resultant matrix* analyzed using game theory portrays the overall incentives for each actor in the dyad for every action pair (e.g. exchange-exchange). Social exchange theory allows the resultant matrix to be decomposed into component matrices. These components have behavioral interpretations not considered when using game theory alone. Thus the game theory/social exchange theory dual gives us both predictive insight into *when* and *why* knowledge exchange occurs under various conditions.

3.2.1 Knowledge Complementarity

In evaluating the propensity to form a relationship, a comparison of the actor's knowledge to be shared must be made. In fact, knowledge is a tradable good whose value lies both in 'existence' and in 'trade'. While there are many reasons for two firms to enter into a relationship (e.g. joint production, product promotion, etc.) we restrict our attention to the intellectual property domain - knowledge exchange behavior in a supply chain channel.

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[1] The theory of interdependence articulates the construct of *Interdependence*. Since the very context of our research is the knowledge domain, hereafter, we refer to knowledge interdependence merely as interdependence.

In establishing a relationship, the characteristic of knowledge that may determine the value as a tradable commodity is what has been called knowledge complementarity. Knowledge complementarity was extended by Kim et al (2012) in their work which we characterize as the adjoining of two distinct bodies of knowledge such that the agglomeration is super-additive; the combined knowledge set has a higher semantic value than the simple additive knowledge of the parts. In work outside the scope of this proposal KC is further developed into distinct types of KC with unique characteristics. For our purpose here, KC is treated as a state variable held constant at a value of 'high KC'.

3.2.2 Inter-organizational trust

Inter-organizational-trust can be thought of as "the willingness to be vulnerable" and having three basic dimensions: competence, benevolence and integrity (Mayer, Davis, Schoorman, 1995). This conceptualization is robust across levels of analysis (Schoorman, Mayer & Davis, 2007) and is applicable when the referent is a dyad of organizations. *Competence* may be described as the belief that the other party can fulfill its end of a commitment. In a supply channel dyad, this relates to a partner's ability to coordinate with its partner and its possession of essential context-relevant knowledge. *Benevolence* is the desire of a firm to act in the best interest of its partner – the absence of opportunistic intent. *Integrity* most closely relates to honesty and can be described as value congruence. For example, is a prospective partner consistent, honest and have a value system compatible with its prospective partner? This is somewhat of a simplification since trust has been characterized using various characteristics.

However, for this research we consider these characteristics as subsumed by the dimensions of competence, benevolence and integrity as explained in Mayer et al (1995; 2007).

Organizations are not, in general, driven by emotions; rather, they are mostly guided by economic interests. Inter-organizational trust is driven by two major factors: (1) self-interest and (2) relational interest. Assessment of competence, benevolence and integrity in a relationship guided primarily by economic interests is a reflection of the firms' incentive alignment. High inter-organizational trust in a supply channel dyad occurs when both actors perceive that its partner firm does not have any incentive conflict in executing commitments to the relationship. For example, a firm may be quite competent in the activities required in the relationship and also hold the belief that the partner is honest and would not cheat (the integrity component) In addition, a partner firm may lack any clear incentive to act opportunistically for lack of any benefit (the benevolence component).

In contrast, low inter-organizational trust occurs when both actors in the dyad perceive that its partner has incentive conflicts when executing commitments to the relationship. The incentive structure creates situations where the best short-term interest of an actor may be to engage in anti-normative behavior. Unlike mistrust or distrust, however, low inter-organizational trust does not necessarily imply hostility, conflict or ill-will between the actors because 'any reasonable person would have acted similarly…' (Lindenburg, 2000). For example, due to weak competence in the activities required of the relationship it may be costly for a partner firm to meet its obligations. Alternatively, the market positioning of the partner firm may create a powerful incentive for it to act opportunistically (the benevolence component). This research side steps the debate whether mistrust is distinct from trust or the opposite end of a continuum with trust and instead accepts the traditional view that mistrust is merely "the absence of trust" (see Schoorman et al, 2007), what we refer to as low inter-organizational trust.

Thus, the levels of inter-organizational trust – high and low – reflect the three well known dimensions of trust in terms of incentive alignments at a firm level.

3.2.3 Interdependence

Dependence of a member in a dyad is the extent of the need for the member to participate in the relationship. *Interdependence* (ID), on the other hand, is the mutual need of the participants in a dyad to be part of the relationship. Thus, interdependence and dependence are distinct but related concepts (cf. Kumar, Scheer, Steenkamp, 1995). It is important to observe that knowledge complementarity and interdependence are distinct concepts; however, there is an important precedence relationship between them. KC is a necessary condition for ID – i.e., ID is impossible unless there is KC. However, presence of KC does not always imply ID. For instance, transactional knowledge exchange as in *ad hoc* consulting services can occur even when KC does not lead to ID. Likewise, even if KC is high, if there are readily available sources of knowledge outside the prospective relationship, then ID can be low. If, however, there are no near equivalent alternatives, or substitutes are imperfect and/or cost-prohibitive, then KC is expected to have a dominant influence on the characteristics of interdependence.

Interdependence has two dimensions: joint dependence (JD) and dependence asymmetry (DA). *Joint dependence* is essentially the sum of the members' individual dependence in the relationship. *Dependence asymmetry*, on the other hand, is the difference between the individual dependence of the members in the relationship.

Knowledge is generated at a cost and represents an investment of time and resources and is a source of competitive advantage for an actor; it is a valuable asset. While some researchers have found that individuals exchange knowledge on social online forums freely and for psychological reasons (Ye, Chen, & Jin, 2006), at the firm level we posit that the knowledge of relevance to inter-organizational knowledge sharing would not be exchanged for nonstrategic purposes. Rather the exchange would be for the creation of shared or indigenous market capabilities.

In a dyadic relationship, two actors will interact through actions - behavior which creates payoff (i.e. cost/reward) for both. Drawing on the early seminal work in social exchange theory (Thibault & Kelley, 1959), we introduce the concepts of comparison level (CL and CL_{alt}) and the payoff matrix to characterize the patterns of interdependence that influence actor behavior.

The previous discussion articulated the constructs descriptively. However to use both social exchange theory and game theory, a matrix representation is needed. While the following discussion is from a social exchange perspective, the mechanics of reading the matrix is the same for game theory.

In the matrix shown in Figure 3.8, we see a dyad comprising of actors A (column) and B (row); the payoffs for the row actor are below the diagonal while the column actor payoffs are the upper diagonal in each cell. For example, the behavior pair (b1, a1) results in a payoff of 1 for row (actor B) and 4 for column (actor A).

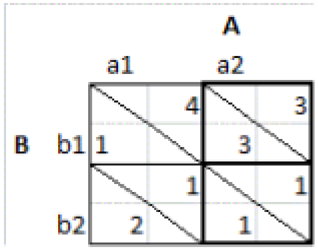

Figure 3.8: Comparison Level

The *comparison level* (CL) is the expected payoff from an interaction that each actor has while CL_{alt} is the expected payoff from the next best alternative to the current relationship; thus, $CL_{alt} < CL$[2]. If the achieved payoff is equal to or greater than CL, the participant will be attracted to the relationship. If the payoff is less than $CL_{alt,}$ that actor would have incentive to leave the relationship. If, however, the payoff is less than CL but greater than CL_{alt} then the actor is 'trapped'; there is no better alternative to the current relationship even though the individual is not satisfied (Thibault & Kelley, 1959).

An actor in a dyad is said to be dependent on the relationship if its next best alternative is significantly worse than the expected payoff from the current relationship; that is, $CL_{alt} << CL$. This gives a less dependent actor power over a more dependent actor. However, dependence in a supply channel can be mutual giving rise to patterns of interdependence.

[2] Note that when $CL_{alt} > CL$, the actor has no incentive to stay in the current relationship and the CL_{alt} would become the *new* CL.

3.2.4 Patterns of Interdependence

Joint dependence and dependence asymmetry together create a pattern of interdependence which will govern the nature of the exchange relationship in a supply channel dyad.

Given two actors (A and B) in a dyad where DEP_a is a measure of the dependence of actor A on the relationship and DEP_b a measure of the dependence of actor B on the relationship. DEP_x (x is either actor A or B) is a numerical index of dependence (Kelley & Thibaut, 1978) which ranges from 0 to 1.0 implying independent and totally dependent respectively. *Dependence asymmetry* (DA) is defined as $| DEP_a - DEP_b |$. Thus, DA can range from zero (no dependence asymmetry), to 1.0 (unilateral dependence).

It is important to emphasize that interdependence (ID) and dependence are *not* the same. We define joint interdependence to be the sum of each actor's dependence. That is $JD = DEP_a +$

DEP_b where JD can range from 0 to 2. If JD is zero, then the actors have no mutual dependence (or need) on the relationship whereas if JD equals 2.00 then both actors are fully, and equally, dependent on the relationship – i.e., there are no alternatives outside the dyad for both the actors. Overall, JD bounds the range of possible dependence asymmetry. For example, when JD equals 2 there can be no dependence asymmetry as both parties have maximum dependence on the relationship; there are no alternatives outside the dyad (CL_{alt}=0). IF JD equals zero DA is not defined; there is no asymmetry when actors are independent. Thus, joint dependence and dependence asymmetry form a space (Figure 3.9) - the collection of all possible JD-DA pairs.

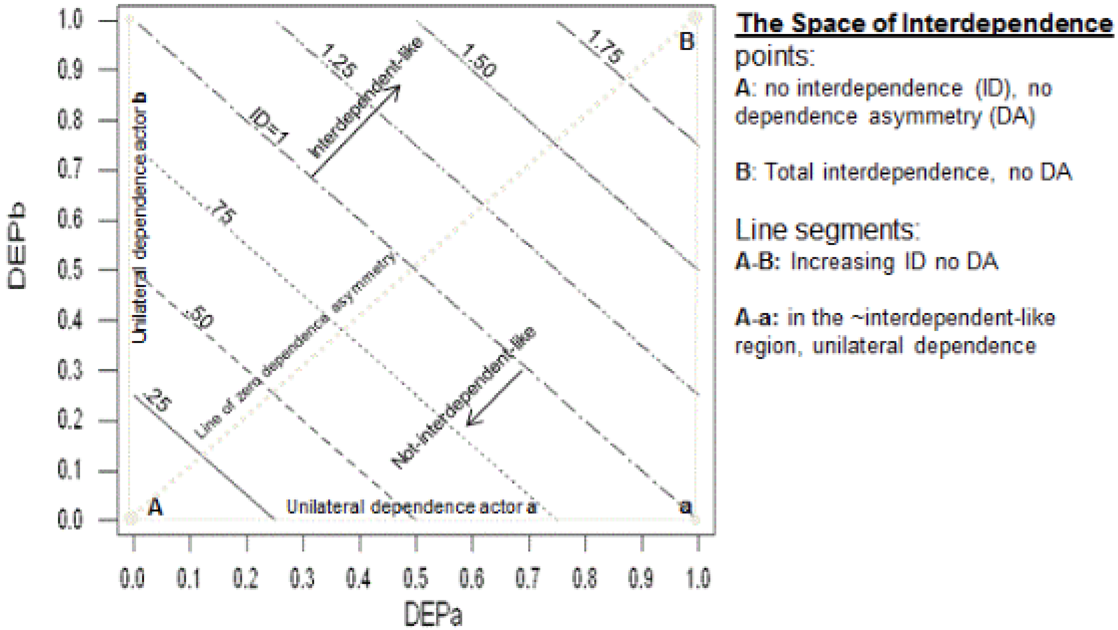

Figure 3.9: The Space of Interdependence

There are two regions in the JD-DA space (Figure 3.9): interdependent-like and ~interdependent-like (not-interdependent-like). *Interdependent-like* is the region where the individual dependence for both actors is sufficiently large that both have at least some *dependence* on the relationship (1 < JD >= 2) irrespective of how large/small the dependence asymmetry is and there can be no unilateral dependence since JD > 1. In the extreme case of total interdependence (JD=2) both actors are maximally dependent on the dyadic relationship and DA must be zero (point B in Figure 3.9). As JD approaches 1.0 in the interdependent-like region, the range of possible DA increases; however unilateral dependence is still infeasible.

~Interdependent-like region portrays where the overall joint dependence is sufficiently low (JD <= 1.0) that one member of the dyad may have little, if any, dependence on the relationship making it largely *independent* in the relationship. In this region *unilateral dependence* where one actor depends on the relationship while the other does not is possible.

The extreme case in this region (point A in the space of interdependence) is where joint dependence is zero; both actors are independent in the relationship. Thus, DA at point A is not defined since neither member depends on the relationship.

3.2.5 Components of Interdependence

In the above section, the conceptual underpinnings of interdependence in terms of joint dependence and dependence asymmetry were articulated. We now turn our attention to the components of interdependence because from these components the game theoretic model's payoff structure will be derived. <u>Thus social exchange theory defines the pattern of interdependence underlying the game-theoretic models.</u>

There are three components to interdependence: bilateral reflexive control, mutual fate control and mutual behavior control (Kelley & Thibaut, 1978). The aggregation of these three components creates the *resultant matrix* which essentially characterizes the dyad's interaction from a game-theoretic perspective – i.e., the normal form game matrix analyzed using game theory. *Bilateral reflexive control* (BRC) is the preferences of an actor in the dyad without regard to *any* contingencies or what the other actor prefers. It is a measure of the payoff which that actor can achieve independent of the other actor. *Mutual fate control* (MFC) is the effect on one actor due to the action of the other over which the affected one has no control. For example, actor A executes an action and actor B is affected no matter what it does in response. *Mutual behavior control* (MBC) is the desire (or lack thereof) of both parties in the dyad for coordination – i.e., how they wish to interact with each other. MBC is a reflection of the coordination requirement of the tasks that dyad is engaged in. The action pairs can either reinforce or interfere with each other.

In the case of BRC (Figure 3.10) we can see that column can get a payoff of 3.00 irrespective of what action row takes. Likewise, row gets a payoff of 2.00 irrespective of what column does. Thus, if the relationship in the supply channel dyad has only BRC there is no interdependence because, each actor can maximize its payoff independent of what the other does. However, if there is interdependence then one or both of the remaining components – viz., MFC, MBC will also be non-zero and have an influence on the resultant payoff structure/matrix.

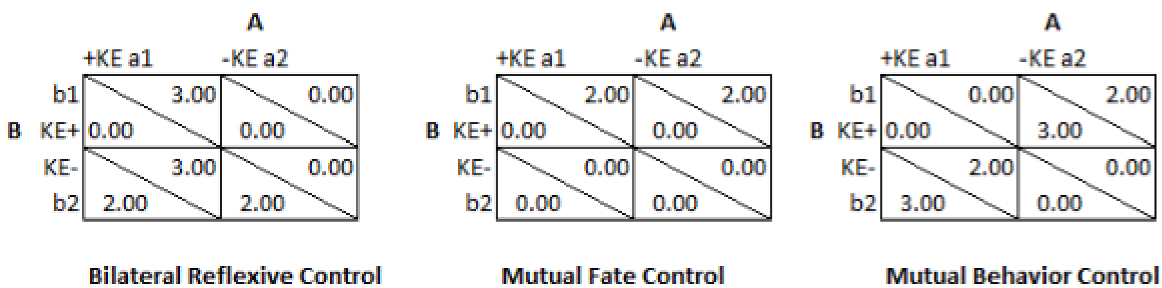

Figure 3.10: The Components of Interdependence

Mutual fate control is the component of an actor's payoff that is influenced by the other actor's actions and there is nothing the influenced party can do about it. For example, if row selects action b1 then column gets a payoff of 2.00 no matter what it selects itself - a1 or a2. If, however, row selects b2 then column receives a zero payoff and has no control over this result.

Before introducing the last component, mutual behavior control (MBC), we should recap the importance of BRC and MFC alone on the overall pattern of interdependence. If BRC was the only component present (a feasible condition) that would mean that each actor is independent and there is no need to even interact with the other actor. If, however, the entries in the BRC matrix were zero (no BRC) then each partner is totally dependent on the supply channel because an actor now can only achieve a payoff conditioned on what the other actor choses – i.e., MFC and/or MBC. When MFC alone is present, the class of relationships is termed as *trade-like* exchange; the interaction is essentially 'tit for tat'. When MFC is absent, there is no trade-like exchange in the relationship and coordination (MBC) and/or preferences (BRC) will inform the relationship.

In an example of pure MBC, we see that row (actor B), when selecting b1, gets its maximum payoff if column (actor A) selects a2 (Figure 3.10). Alternately, if row selects b2, it would 'prefer' column to select a1. It should be noted that in this example, actor A's (column) preferences would follow the same logic. The actors achieve their individual best outcome by cooperating with the other.

3.2.5.1 The resultant pattern of interdependence

The previous section described the three component parts of interdependence defined in social exchange theory. The aggregation of behavioral components reflecting supply channel situations as it relates to member firms preferences (BRC), firms being subject to partner influence (MFC) and shared desires of the dyad for coordination (MBC) determines the pattern of payoffs in the game theoretic model from which research hypothesis pertaining to when and how KEB ought to occur are derived.

Given the three components of interdependence, viz., BRC, MFC, MBC, the resultant pattern of interdependence can be computed as shown below. The resultant payoff matrix essentially *is* the normal form game theoretic model[3].

Using the previous example showing BRC, MFC and MBC we can see how the resultant matrix (shown next) is derived by the aggregation of each component matrix. For example, pair b1-a1 results in a payoff of 4.00 for actor A; that is, 3.00 + 1.00 +0.00 from BRC, MFC and MBC respectively.

Having identified the underlying components of interdependence, viz., BRC, MFC, MBC, we can revisit how the index of dependence and interdependence are calculated (Kelley & Thibaut, 1978).

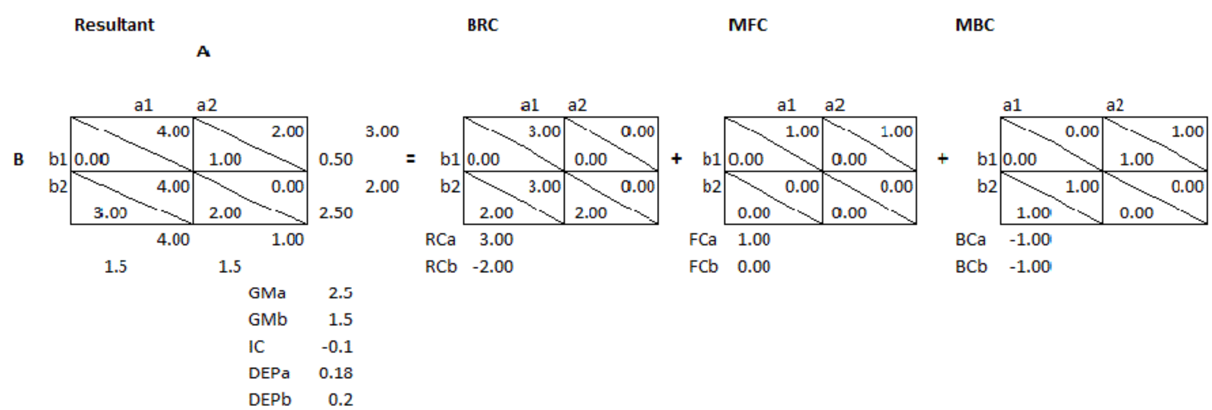

Figure 3.11: A Resultant Matrix and its Components

FC, BC and RC (Figure 3.11) are called *control values* for MFC, MBC and BRC respectively and are the basis for arriving at the degree of dependence of an actor in the dyadic relationship. FC, BC and RC are calculated from the resultant matrix – the details of

[3] Game theory uses either an extensive form (directed graph/inverted tree) or a normal/strategic form (matrix) to represent a game model. Please see appendix E for an example of each form.

computation are included in Appendix A. Dependence of an actor in the relationship is computed as:

$$DEP_x = (FC_x^2 + BC_x^2) / (RC_x^2 + FC_x^2 + BC_x^2)$$

RC_x^2 (calculated from the BRC matrix) is the index of what actor X can achieve independent of any relationship. Thus, if RC_x^2 is zero, actor X has no independent ability to generate a payoff from its actions alone; it is dependent on the other actor in the supply channel dyad. On the other hand, if RC_x^2 is positive and both FC_x^2 and BC_x^2 are zero, DEP_x is zero meaning the actor is not dependent on the supply channel relationship at all. Likewise, if RC_x^2 is positive, unless both FC_x^2 and BC_x^2 are zero, actor X has some dependency on the supply channel relationship. The range of values for DEP_x and DEP_y is 0 to 1. For instance, in Figure 3.11, dependence of A in the dyadic relationship is 0.18 and that of B is 0.2. Thus the joint dependence is 0.38 (0.18 + 0.20) while the value of dependence asymmetry is 0.02 (| 0.18 - 0.20|). Accordingly, it is obvious that the resultant matrix reflects low joint dependence and an almost non-existent dependence asymmetry. Dominance of the BRC component here clarifies this condition.

We thus have introduced patterns of interdependence, which model the influence of levels of JD and DA. Table 3.1 is a summary of these conceptualizations.

Table 3.1: Dimensions of Interdependence

Joint Dependence (JD)	**BRC**	**MFC**	**MBC**	**Dependence Asymmetry (DA)**
No JD [a]	Totally dominant	Absent	Absent	Not defined [b]
Total JD	Absent	Possible	Possible	Not possible [c]
Partial JD [d]	Present	Possible	Possible	Possible

[a] When no JD, there is no opportunity to coordinate (MBC absent) nor is either actor influenced by the other (MFC absent).

[b] With no JD, neither party has a need for the relationship; dependence asymmetry, then, is rendered meaningless.

[c] Under total JD each actor is maximally dependent on the relations. Dependence asymmetry is not possible because neither has an alternative outside the relationship.

[d] Under partial JD, at least one of MFC/MBC must be present; BRC is present.

3.2.5.2 The effects of the pattern of interdependence on incentive structure

The resultant matrix represents the aggregation of the behavioral components and serves as the 'game' that the two member firms are playing when exchanging knowledge. The components matrices are the behavioral implications of that exchange.

The incentive structure reflected in the game/resultant matrix is embedded in the pattern of interdependence. Two distinct properties of the pattern of interdependence amongst BRC, MFC, MBC, influence the incentive structure. They are: concordance/discordance and correspondence. The relationship between the component matrices is called concordance (or discordance). *Concordance* results when the preferred action pair between two component matrices reinforces each other. If the preferred action pair between two component matrices interferes with each other *discordance* is the consequence. Concordance/discordance relates to the 'fit' *between* pairs of component matrices – BRC-MFC, BRC-MBC and MFC-MBC.

Correspondence, on the other hand, is defined as the degree to which an actor's preference aligns or conflicts with the other actor in the dyad. Since correspondence is the joint preference between two actors, it relates to the structure of the MBC or resultant matrix. The BRC and MFC matrices relate only to an individual actor's preference without regard to its partner. Therefore, correspondence has no meaning for the BRC and MFC matrices. There are three levels of correspondence: goal congruence, goal conflict and indifference.

As an example, suppose two people wish to travel together. If one wants to drive and the other wishes not to drive these preferences would be correspondent. Conversely if both wish to drive then their preferences would be non-correspondent. Thus, correspondence is the degree of alignment in preferred action *within* a single matrix – MBC or resultant. Similarly, the case where one wishes to drive while the other does not results in concordance among the component pairs MBC and BRC. The task coordination requirements conveyed in the MBC component requires that one person drive and the other not drive. Since this is also what each member wants to do, the MBC component is concordant with the BRC component. Similarly, each member wishes the partner to do the opposite of his/her own preference; therefore, the BRC and MBC components are concordant. They agree that one should drive and the other does not.

The dual properties of correspondence and concordance/discordance[4] impact the incentive structure of the resultant matrix. In the pristine case where the resultant and MBC matrices are correspondent (that is, both actors have aligned goals) and there are no discordant component pairs for either indicates total incentive alignment in the dyad. Similarly, a non-correspondent resultant matrix and discordant component pairs represent incentive misalignment since there are incentive conflicts.

To illustrate total incentive alignment, let us consider a well-known game called the *Stag Hunt* (Figure 3.12). Two hunters can work together to capture a big animal or they can each go their own way and settle for a smaller animal with less payoff for each. The game shown below indicates that the best achievable outcome for both is to work together and there is no incentive to cheat - please note the values DEP_a and DEP_b of in the resultant matrix are 1.0 (total dependance).

[4] Concordance/discordance can be seen as equivalent to the concept of "coupling" in software engineering. Likewise correspondence is akin to "cohesion".

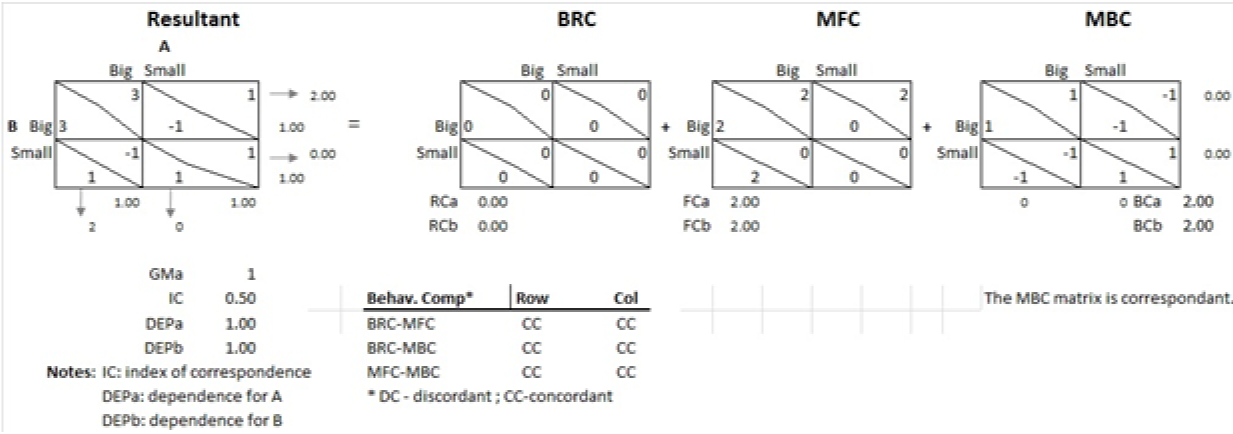

Figure 3.12: The Stag Hunt Game

Neither actor has the capability for independent action – the BRC has all zeroes entries – because the hunter depends on what his/her partner does. However, each prefers the other to go for the big animal; big-big on the MFC. The MBC matrix is the coordination requirement of the task. Here it simply means they are best off doing the same thing: big-big or small-small. The task coordination requirement (MFC) is indifferent to which choice is made. However the MFC induced action pair has both preferring the other target the big animal. This does not result in any payoff loss on the MBC matrix since coordinating their actions maximizes both getting the maximum gain because the MBC matrix is **correspondent**. The coordination requirement does not impose a loss on either actor because the MFC and MBC matrixes are **concordant**. Also, the resultant matrix like the MBC component is correspondent.

The Stag game would therefore be considered to represent the pristine case of incentive alignment because there are no incentive conflicts. Since the payoff structure is common knowledge – each actor knows her/his partner's preferences – there is no reason to fear opportunism from her/his partner.

3.3 The confluence of two theoretical perspectives

The basic premise underpinning knowledge exchange behavior is the very existence of significant knowledge complementarity in the dyad – i.e., the supply channel. Granting the presence of significant knowledge complementarity, the engagement between the partners in a supply channel can be one of opportunistic behavior predicated on self-interest or one of cooperative behavior based on relational interest. In an inter-organizational interaction such as knowledge exchange both behaviors are triggered by the prevailing incentive structure in the specific engagement – knowledge exchange engagement in a supply channel.

Game theory articulates the rationale for self-interested behavior seeking individual payoff maximization in the supply channel engagement. Relational view of an inter-organizational engagement, viewing the engagement as a "relationship", seeks to maximize relational rent for the supply channel (joint payoff) due to the presiding cooperative behavior.

When inter-organizational trust is low, there can be no inclination on the part of the engaging partners to willfully cooperate since both are concerned about the possible opportunistic behavior by the other. Thus, the partners seek to maximize individual payoffs – the game theory solution. When inter-organizational trust is high, the supply channel partners can be expected to gravitate towards a cooperative behavior in order to gain the often higher relational rent – i.e., joint payoff – even risking the possible (not probable, though) non-cooperation by the supply chain partner; after all, the engagement is a "trusting" relationship.

As an example, shown below (Figure 3.13) is the game for the popular Prisoners' Dilemma (PD) where two thieves have been apprehended by the police for an infraction.

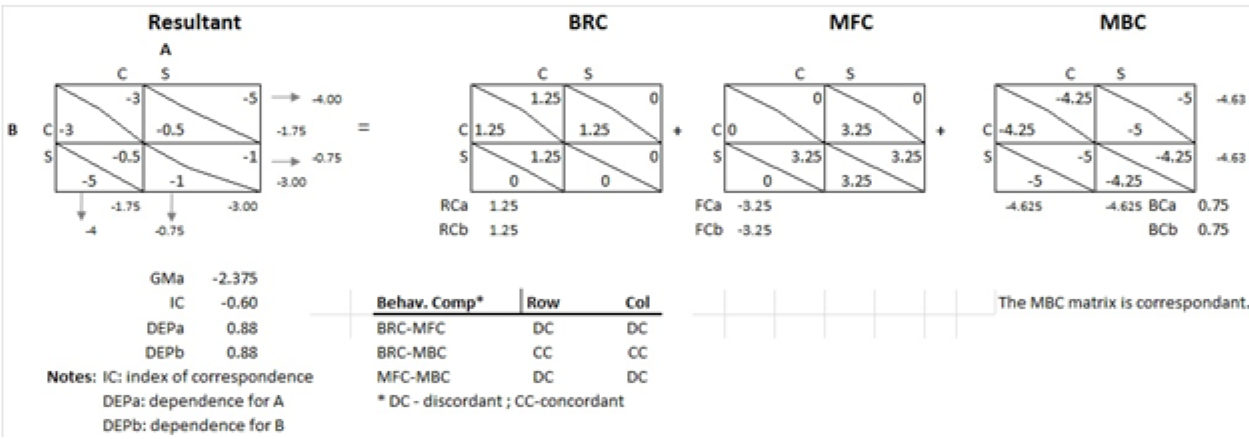

Figure 3.13: The Prisoners' Dilemma

The choice for each is to either cooperate with the police and confess (C) or stay silent (S) (i.e. not respond to the police's inquiry). If neither confesses then both get off with one year in jail [-1, one year in jail] – not the best individual outcome for either; essentially their second best outcome. If, however, one confesses and the other is silent then the one who confessed goes free in 6 months – the best possible individual outcome [-.5, 6 months in jail]– while the other suffers the full penalty of law (the worst outcome, [-5, 5 years in jail]).

Now, let us review the incentive structure latent in the game matrix revealed by the decomposed component matrices. Each actor prefers to confess (BRC) which is precisely what the other prefers him/her *not* to do (MFC). Thus, the BRC-MFC pair is discordant. However, they both could 'cooperate' by simply acting on their own preference as indicated by the concordant BRC-MBC pair. The discordant MFC-MBC pair indicates that while both want to do what the other one wants to do - either keeping silent or confessing – (Correspondent MBC), both want the other one to *not* do what s/he wants to do. The incentive misalignment is obvious.

Enter trust! - In fact, here, the lack of it. Two complementing forces are in play. Neither wants to take the chance and be 'silent' and receive the full force of law (5 years in jail) fearing the other 'confessing'. Also, there is a powerful incentive for each to act opportunistically in the hope of getting the 'suckers payoff' [-.5, 6 months in jail], i.e., one expecting the other to remain silent while himself/herself confesses. Thus, both end up 'confessing' and receive a jail sentence for 3 years each [-3, -3]; individually smart, collectively dumb! Both confessing will result in each getting the 'least bad' outcome [-3, 3 years in jail] rather than the worst possible – 5 years in jail – a Nash equilibrium. This is a *deficient* outcome – together they could have done better by remaining silent. In this case, this is the classic game theory solution.

The relatively superior solution for this dilemma is for both to stay 'silent' and indeed they would have, had they been Bonnie Parker and Clyde Barron from Texas; after all their relationship is forged by a high level of trust. The high mutual trust precludes them from opportunistic behavior; in fact, each would willingly be sacrificial and take the slight risk of the other not cooperating deliberately or inadvertently. Thus, they are expected to end up with the best joint outcome of one year in jail [-1, -1] even though it is not the best individual outcome for either - a Nash equilibrium which is also Pareto optimal. In essence, in this solution the relational rent is maximized[5].

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[5] The evolution of trusting behavior in a supply channel context over repeated engagements over time is an interesting issue for future study (see Axelrod, 1981).

We have used the theory of interdependence to articulate patterns of interdependence that have behavioral consequences. The resultant matrix derived from these behavioral components can in turn be analyzed using game theory or the relational view.

There are 78 prototypical games which can be manipulated to form any possible 2 x 2 game – i.e., resultant matrix (Rapoport, 1967). The game matrix is decomposed into the BRC, MFC and MBC matrices to reveal (1) the latent incentive structure and (2) the levels of interdependence. Some fine-tuning of the component matrices is often necessary to accurately capture the levels of interdependence. The aggregation of the fine-tuned component matrices provides the resultant matrix for deployment as the game matrix reflecting the resultant incentive structure.

Some of the prototypical games may not have any solution (e.g., the game known as the battle of the sexes); such games are of no value to this research. Alternatively, a game may have more than one solution:

- Strategy 1: seeks to maximize individual payoffs (Game-theoretic strategy);
- Strategy 2: seeks to maximize joint payoff (Relational strategy)

It must be noted that sum of the individual payoffs can never exceed joint payoff. Sometimes, the incentive structure of the game matrix can yield the same solution for both the strategies – i.e., the same payoff for both strategies.

At this point, the stage is set for the development of hypotheses of interest to this research. The reader is reminded that the basic premise underlying the hypotheses development is: the prevailing condition facilitating the supply channel engagement is one of high knowledge complementarity.

3.4 Hypothesis development

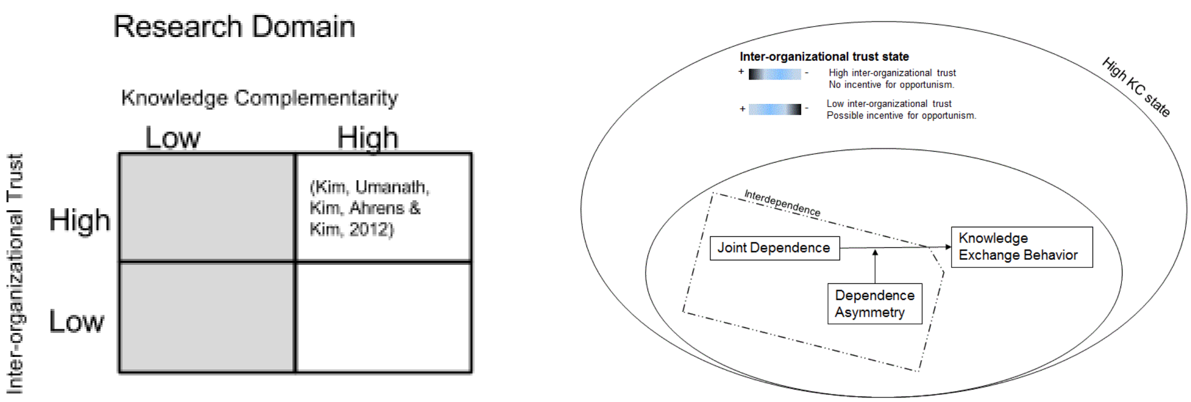

Figure 3.14: The Research Domain

Figure 3.14 above marks the boundary of the current research. When knowledge complementarity is low, joint dependence is, at best, low, if not, absent; and dependence asymmetry, if any, has to be necessarily low also. This is empirically confirmed by a recent study (Kim, et al., 2012) - the left two cells, grayed out, are conditions of low KC. Our investigation is focused on the high knowledge complementarity state - the right column in the figure.

The other variable in our research domain is inter-organizational trust. The upper right cell - high inter-organizational trust and high KC - is where the Kim, et. al., (2012) study had hypothesized that positive knowledge exchange would occur but in fact found the diametrically opposite result.

The context of the phenomenon is the condition of high KC. Our thesis is that KEB is not just a function of knowledge complementarity and states of inter-organizational trust. In fact, KEB is also a function of the knowledge interdependence prevailing in the dyad among other things which are outside the scope of this investigation (e.g., commitment, and other unmodeled antecedents).

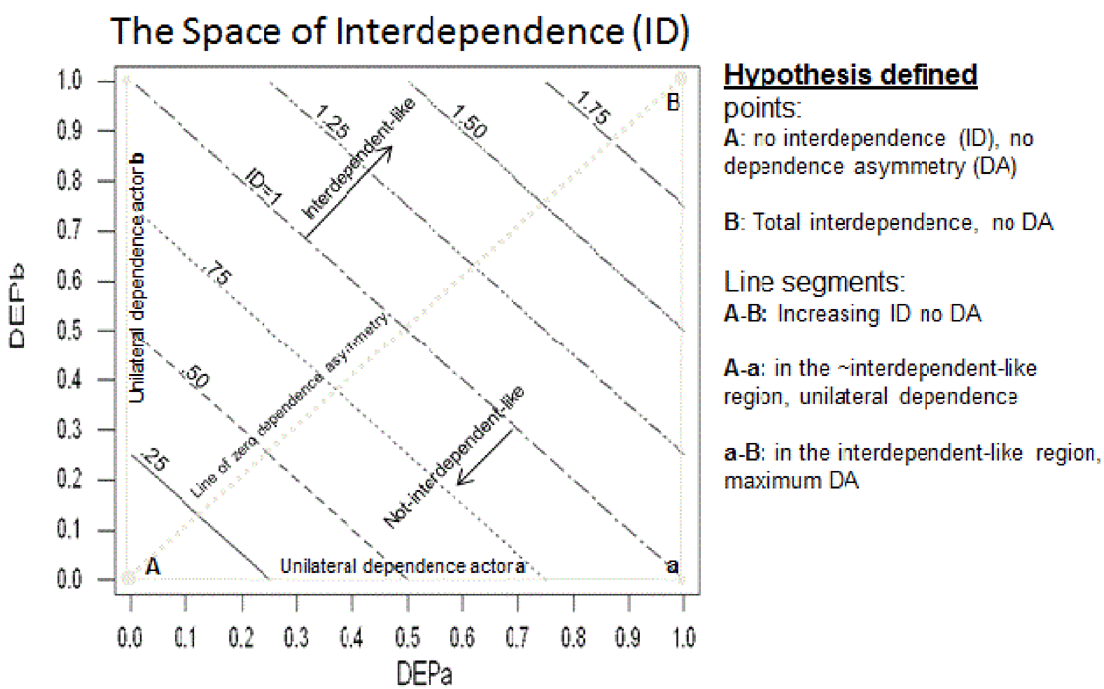

Figure 3.15: Hypothesis and the Space of Interdependence

That said, the ID space comprising JD-DA spans the supply channel conditions of interdependence and facilitates the development of the hypotheses. As shown in the space of ID (Figure 3.15), we consider the case of high JD, low JD, increasing JD with no DA, and unilateral dependence in the ~interdependent-like region.

The interaction between the two members in the dyad is reflected in the 2 x 2 resultant matrix which is the payoff for every action pair between the actors. This underpins the development of the hypotheses while its decomposition provides the behavioral interpretation of the predicted action. While game theory and social exchange theory are complementary perspectives, they can yield conflicting results or 'solutions'. A purely game-theoretic solution is concerned only with an actor achieving its own best payoff in view of what its partner is likely to do. No consideration is given to the joint interest of the dyad. In situations of low inter-organizational trust, each actor is expected to seek maximization of its own gain since there is no reason to sacrifice its own best payoff absent an expectation of reciprocity from its partner. Thus, hypotheses for low inter-organizational trust tend to be game-theoretic solutions.

In contrast, in a high trust condition both members of the dyad seek to keep trust with its partner by not seeking supernormal returns for themselves if/when joint payoff is compromised. From a TID perspective the actors seek to maximize the joint payoff (i.e. the combined payoff) because this makes the relationship more attractive to each partner and reduces the attractiveness of alternatives to the dyad. Each actor derives benefits from engaging in the relationship and is willing to make potentially nominal sacrifices (i.e. forgoing individual best outcomes, if need be) to maintain it. Central to this behavior is the idea previously discussed concept of an actor's comparison level (CL) – the expected payoff - to that of its alternative comparison level (CL_{alt}); the payoff that can be achieved outside the existing relationship. If $CL > CL_{alt}$ the actor(s) is attracted to the relationship. Thus, by seeking to maximize the joint payoff each actor is spared the need to develop, at a cost, alternatives with a higher CL_{alt}.

This also underpins the idea of relational rents described in the alliance literature (e.g. Dyer & Singh, 1998). *Relational rents* arise when a relationship creates more value than what could be created individually. It is also super-additive meaning that the combined outcome exceeds the simple sum of the individual parts. Thus, in addition to avoiding the cost of developing alternatives, maintaining the relationship generates superior returns to an actor even if it foregoes its individual best outcome to maintain the arrangement.

Thus, when 'solving' a game, the TID solution may be diametrically opposite to the game theoretic solution. The Prisoner's Dilemma game is a well-known example. From a purely self-interested point of view each actor would defect and be worse off for it. However, from an TID perspective cooperation yields a superior result. Thus, the high inter-organizational trust hypotheses tend to be governed by the social exchange perspective as cooperative relationships are expected to be richer than merely incentive driven engagements.

Knowledge sharing between partners may often be beneficial to both partners in the engagement, but is not a costless event. The very value of the knowledge often varies; in addition, there are costs associated with the process of sharing (e.g., educating, training, etc.). In making the decision of whether or not to give/receive knowledge, the following factors may be relevant:

- the benefits from being able to combine the firm's knowledge with that of a partner.
- the risks of integrating the knowledge into the firm
- the risks of losing control over the knowledge

- alternative sources of knowledge in the market

These costs are key precepts of absorptive capacity (see Cohen & Levinthal, 1990) where the barriers to exchange between a sender and recipient depend on the ability of a recipient to assimilate new knowledge. This also underpins the idea of knowledge complementarity in its expanded definition (Kim et al, 2012). Absorptive capacity is influenced by the existence of prior related knowledge and the diversity of the knowledge when compared to the existing base. This research applies the framework of absorptive capacity to define three distinct types of knowledge exchange behavior: promote, retard and attenuate (with two sub-types that are isomorphic).

Because the two members in a dyad may have different costs to assimilate knowledge relative to each other the exchanges of knowledge need not be two-way. The possibilities to exchange knowledge include both members contributing and receiving knowledge – a two-way exchange - or it can be a one-way exchange where one member provides knowledge while the other receives (and presumably acts on) knowledge.

The types of KEB that *can* occur are introduced by using a state-space diagram (Figure 3.16). Each region is a type of knowledge exchange that is distinguishable from other types. While there are gradations within each they all share common dominant characteristics. The axes are each members cost to absorb knowledge and each point in the plane is a combination of member costs. For example, point $\mathbf{R_c}$ is where both members (x,y) cost to absorb is equal. In fact, here the cost to assimilate knowledge is so high for both that neither will provide (nor receive) knowledge. This type of knowledge exchange behavior is referred to as KEB *retard*.

The members cost to absorb knowledge need not be equal. For example, point **R** represents the case where [x] has a higher cost to absorb knowledge than its partner [y]. However, this combination is still in the same region (regime) and is still considered KEB retard. In this representation unless a boundary is crossed the **type** of knowledge exchange (promote, retard and attenuate) remains the same[6]. This means the general characteristic of the exchange process are treated as the same in this research.

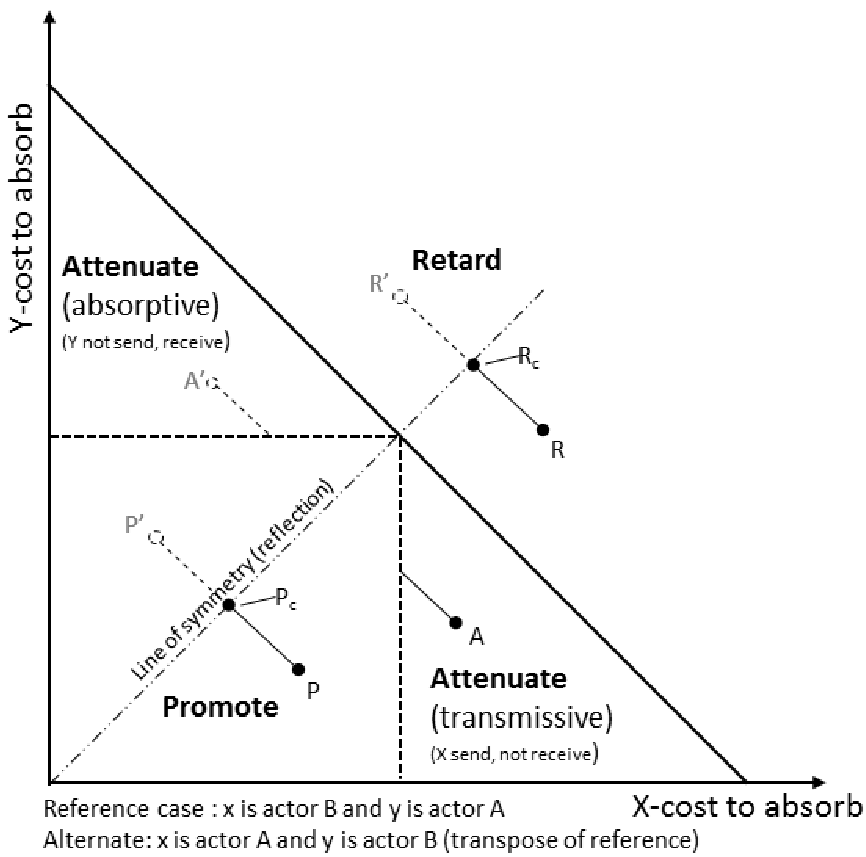

Figure 3.16: A State-Space Diagram of Knowledge Exchange Behavior

The effect of swapping actors in a dyad is simply to reflect across the line of symmetry (dashed centerline in figure). Thus, point **R** previously described becomes **R'** if the x actor is

[6] The case of asymmetric KEB within a region – like point R' in the diagram - is explored in the working paper by Ahrens and Umanath (2014).

swapped with y actor. For clarity in presentation, the rest of this discussion uses the x-actor (the row actor in a matrix representation) as the reference actor.

If both actor's cost to absorb knowledge is low enough, they can both transmit and receive knowledge profitably. This is referred to as KEB *promote* because a two-way exchange of knowledge is not too costly to either actor. Thus, point P – and its reflection from swapping actors **P'** – is still KEB promote.

If, however, there is a large difference between the actors' cost to absorb knowledge then one of two one-way knowledge exchange processes can occur which we refer to as *attenuate*. If the cost to absorb knowledge is much higher for actor x than its partner, as in point **A,** then actor x would prefer to not receive knowledge but instead just send since it is cheaper for its partner to absorb knowledge. This is a case where a dyad member can easily provide its own knowledge stock to the partner but would have difficulty absorbing new knowledge itself. This is referred to as *transmissive attenuate* because the reference actor [x] is transmitting knowledge to its partner.

This 'directionality' has little significance in a supply channel dyad because simply swapping actors creates a reflection of the original condition while the underlying incentive structure is unchanged *between* the actors (see Rapoport (1967). If point A in the transmissive attenuate regime were reflected across the line of symmetry by swapping actors it would become **A'**- a region we term *absorptive attenuate* because now the reference actor (previously x, now its erstwhile partner y) is absorbing knowledge but not sending. This can be illustrated by the example shown in the Figure 3.17 where two members in a supply channel dyad swap roles in the relationship but nothing else about either member has changed. In the transmissive attenuate case (left panel) the reference actor [x] is the buyer who supplied knowledge to a supplier [Y]. This can be thought to represent a sourcing arrangement where a supplier builds to a buyer's specification – contract manufacturing (e.g. Apple/Foxconn). By switching roles (right panel in figure) the flow of knowledge between the actor's reverses – the buyer now receives knowledge from its supplier. This might represent an outsourcing arrangement where a buyer is purchasing outside expertise.

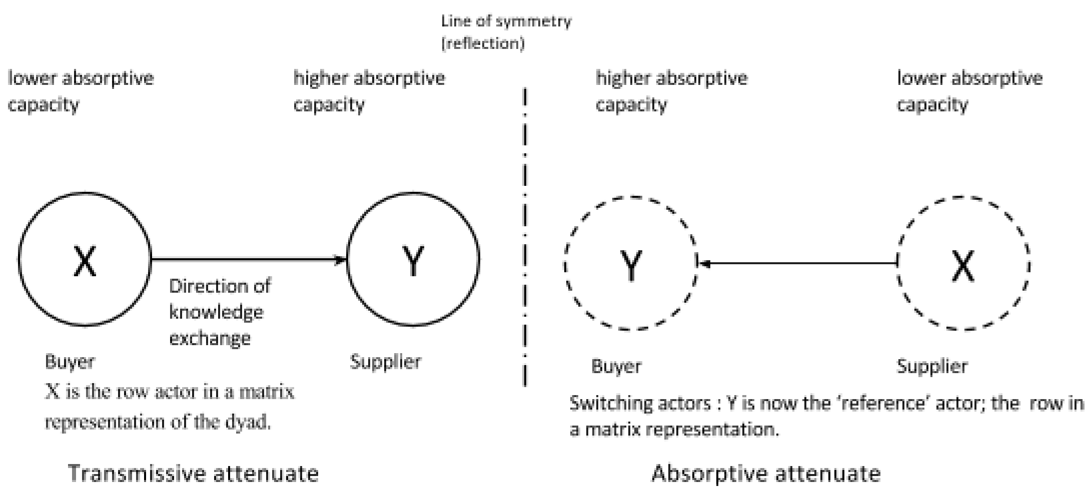

Figure 3.17: The Equivalence of Directionality for Attenuate Knowledge Exchange Behavior

The focal phenomenon studied in this research is indifferent to the distinction of actor roles and since the incentive structure within the dyad is unaffected by swapping actors, only the term *attenuate* will be used in the hypotheses[7].

Thus far, this framework has focused only on knowledge assimilation costs because absorptive capacity only relates to the costs of receiving knowledge and thus provides a powerful

[7] The reason a distinction is made at all between the two types of 'attenuate' is that the analytical representation of KEB uses a vector to model the supply channel response and can discern between the types of 'attenuate'. This is an artifact of the analytical representation described in Section 4 (the analysis section).

framework to define knowledge exchange behavior in this research context. There is, however, a cost to *transmit* knowledge. This is largely associated with the risk of losing control of that knowledge (further described in Kim et al, 2012). There are also logistical costs in providing that knowledge (e.g. training the recipient, preparing materials, etc.). Articulation of the costs to transmit knowledge falls outside the absorptive capacity framework and would require additional conceptual development (e.g. introducing transaction cost economics) which does not support the research direction of this work. Suffice it to state here that theories clarifying cost of transmission of data, information and knowledge do exist.

While we focus only on the cost of receiving knowledge, the effects of transmission cost are treated as an externality which affects both members in the dyad equally. In our framework, the cost of transmitting knowledge affects the size of the KEB regimes as illustrated in the regime diagram shown in FIgure 3.18. In essence, the 'transaction cost' [knowledge transmission cost] simply scales regions of knowledge exchange.

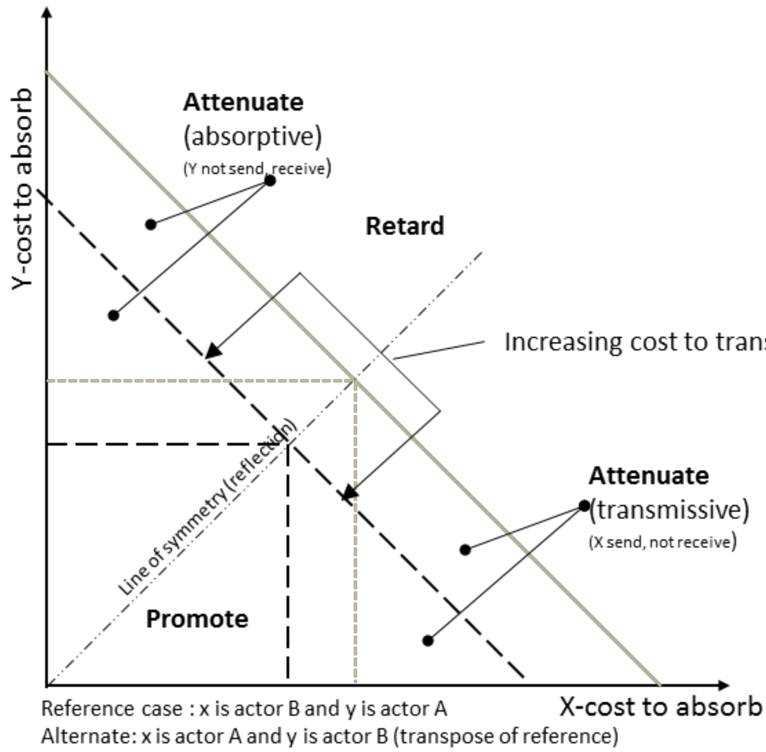

Figure 3.18: The Effect of Increasing Transmission Cost on Knowledge Exchange Behavior

As the cost of transmitting knowledge increases, the KEB retard regime increases in size relative to the other KEB types since the cost of knowledge absorption must now be lower for one or two-way knowledge exchange to be profitable. Conversely, as the cost of providing knowledge decreases, the size of the region where KEB is promoted increases. Indeed, this is a central effect of the widespread 'digitization' of knowledge. For example Kim, Umanath & Kim (2006) found electronic information transfer was facilitated when coordination cost [including cost of knowledge transmission] was reduced.

Implicit in the scaled representation just described is that the cost of transmission is equal for both members – a limitation of this research that will be addressed in a later extension.

3.4.1 Hypotheses for knowledge exchange behavior

With the types of knowledge exchange behavior defined we can now develop the hypothesis for each of the eight environmental conditions (four levels of interdependence and two trust states) as shown in Figure 3.19.

Group	Interdependence	IO Trust
1	Low	Low
		High
2	Moderate	Low
		High
3	High	Low
		High
4	High dep. assy	Low
		High

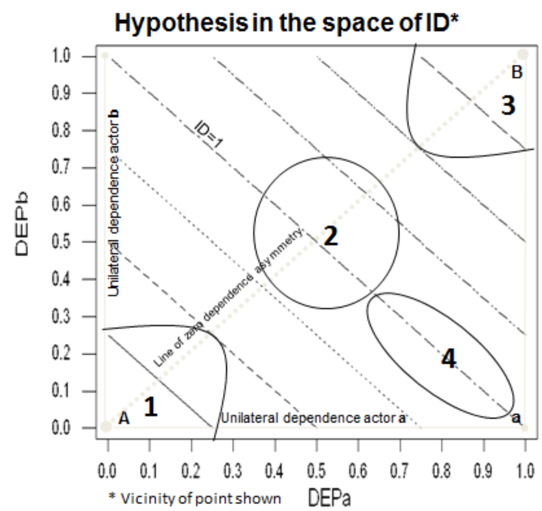

Figure 3.19: Factor Levels and Hypothesis defined in ID Space

The development follows the logic shown in Figure 3.20. For each of the four levels of interdependence a short vignette is presented to create an intuitive basis to understand the business context. Next, using the tools from the theory of interdependence a game matrix is

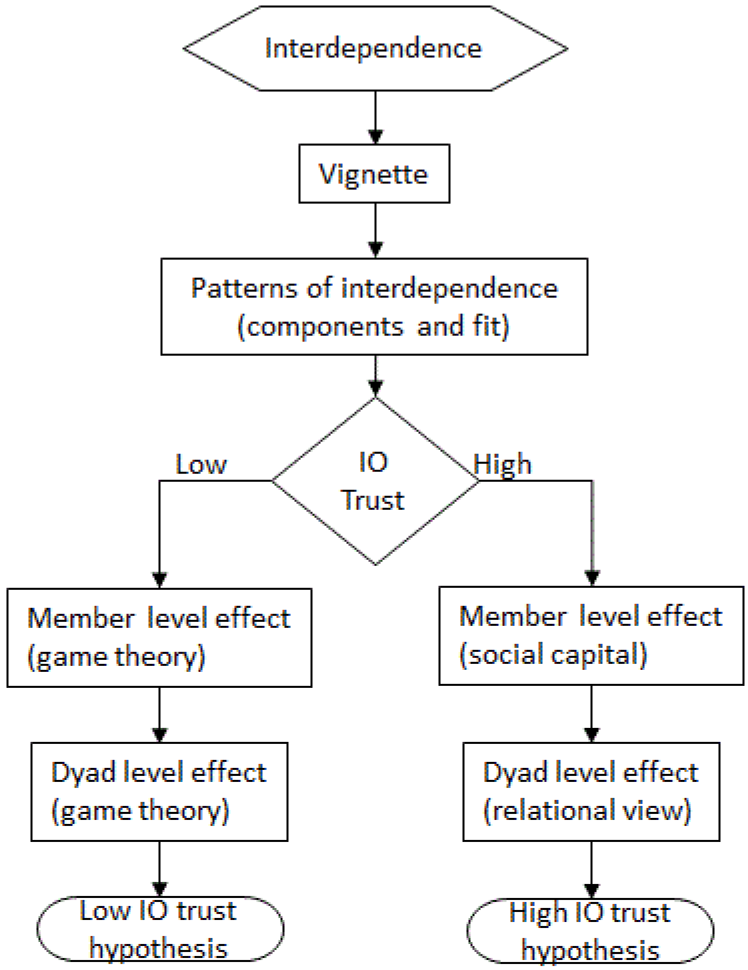

Figure 3.20: The Development of the Hypothesis

presented and the behavioral components and their fits are presented as it relates to each member and the dyad. These relate only to the incentive structure which influences the interaction. Then the logic flow branches at the high and low inter-organizational trust states (low/high). Depending on which trust state is present, the actors may react differently to the prevailing incentive structure. This response is first considered at the member, then the dyad level, using the appropriate theoretical perspective. Then the low and high trust hypotheses are stated.

3.5 Low interdependence

Starting with the case of low interdependence (in the vicinity of point A in the space of ID) we can consider two firms in a dyad each with a low level of dependence on its partner. This is due to both members having accessible alternatives to the relationship and the ability to secure most of its best outcome independent of its partner's action. From the perspective of social exchange theory, the achieved benefit from the relationship may not be much more than the payoffs from alternatives - i.e., $CL <= CL_{alt}$. This is because there are accessible alternatives for nearly independent actors while the cost in a referent dyad may be high.

A recent example may be the erstwhile collaboration between Ford and the Firestone tire company prior to the 2001 Ford Explorer rollover problems. Harvey Firestone and Henry Ford were personal friends and their respective firms had a long standing business relationship. Both firms, however, were relatively independent since Firestone could (and did) design its own tires and associated knowledge of production processes just as Ford developed its own intellectual property relating to automotive design and production technology.

3.5.1 Patterns of interdependence

To model a relationship with low interdependence a game whose decomposition has a comparatively large BRC component - the actors can mostly determine their own payoffs independently. The resultant matrix in the game shown below (see Figure 3.21) indicates that either actor can get no worse than its second best payoff (ex. [8] for the row actor) even if its partner acted irrationality. The worst that the row actor would get if its partner acted adversely to its interest is 9/9.5, or 94.7%, of its best payoff based solely on its own action; a similar case for its partner who, at worst, would get 6/7, or 85.7% of its best outcome. This is because the BRC component dominates. In the case of Ford and Firestone each can find an alternative partner.

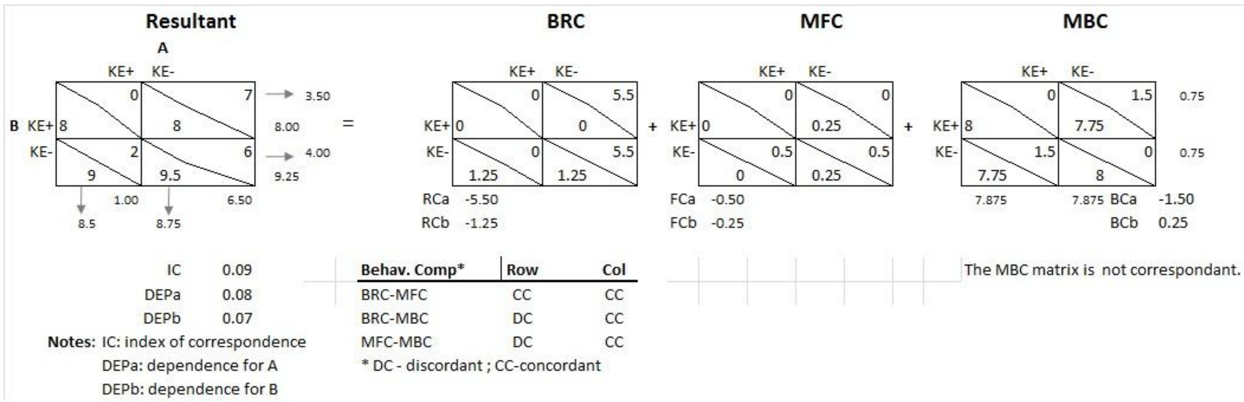

Figure 3.21: Low Interdependence

The BRC component expresses each member's preference which, in this case, is to not share knowledge. This would reflect the comparatively high cost of providing knowledge either due to concerns about opportunism and costly mitigation or simply the logistical cost (e.g. training, time, personnel, etc). Similarly, each member prefers that its partner not provide knowledge – the MFC component- because this would impose a cost to the knowledge receiver due to limited absorptive capacity. The task coordination requirement (MBC) is non-correspondent – cooperation imposes a cost.

3.5.2 Member-level effects: low IOT

If the firms lack inter-organizational trust – as happened with Ford/Firestone after the scandal - each member will seek to maximize its own gain based on its expectation that its partner will have a similar motivation - a strategy akin to game theory prescription. Here, row sees that its two best payoffs ([9] and [9.5]) occur if it chooses KE- because that is its dominant strategy.

This is also true for column and both know each other's dominant strategy and condition their respective actions accordingly – KE-.

Also, while the task coordination requirement (MBC) would have a member coordinate its action with the partner, the fact is that BRC dominates the payoff for each member (i.e., RCa & RCb are significantly higher than BCa & BCb respectively - see Figure 3.21) . This means that disregarding the coordination requirement does not entail a large cost to either party.

In our example, Ford [Firestone] would have a cost if it tried to coordinate with its partner. It would be costly for either member to transmit its knowledge to its partner because the intended recipient would be required to learn from a very low level of familiarity. Likewise, the recipient would be receiving know-how that may be novel, but has limited or no applicability to its current knowledge stock.

3.5.3 Dyad-level effects: low IOT

Since both members are independent of each other for knowledge (dominant BRC) and would prefer the other to not share (concordance of BRC and MFC) both are better off acting only out of individual self-interest; the dyad outcome will be the solution that arises when each member pursues its best individual payoff as prescribed using game theory. Here KE- is the dominant strategy for both yielding 9.5 for row and 6 for column.

3.5.4 Member-level effects: high IOT

On the other hand, if the trust between firms is high, as was the case before the rollover incidents of the Ford Explorer, both Ford and Firestone would consider not only their own immediate individual payoff but rather the means to preserve its membership in the relationship with the other as enunciated by the social capital perspective. Membership in a relationship confers the right to appropriation of benefits unavailable outside the relationship. A member would be motivated to 'pay its dues' to maintain this association.

This does not always mean, however, that knowledge needs to be exchanged to facilitate a pro-relational orientation. In view of the costs of knowledge assimilation a member may, in fact, be imposing a penalty on its partner by pushing knowledge that its independent partner does not benefit from.

The game modeling low interdependence here (Figure 3.21) shows that each member would prefer not to receive knowledge – the MFC component. Thus, a member would wish to avoid imposing a cost on its partner. For example, Ford may not wish to impose a costly learning process on Firestone by trying to persuade it to assimilate knowledge (e.g. production processes) that Firestone would not benefit from receiving.

3.5.5 Dyad-level effects: high IOT

Since each member would seek to avoid imposing a cost on its partner - in this case by providing knowledge that is more costly to absorb than its benefit – a rent is generated by withholding knowledge. The dyad as a whole is better off if these two independent actors did not exchange knowledge. This does not mean that the relationship is dormant but rather that the exchange does not involve sharing knowledge. For example, Ford and Firestone could produce their products independent of knowledge exchange (beyond operational coordination) but benefit in other areas such as co-branding, operational gains, etc.

Observe that the game theory solution (low IOT) and the knowledge sharing strategy based on relational view (high IOT) happen to be the same (KEB retarded) when interdependence is low essentially indicates that IOT is irrelevant when the interdependence of the dyadic engagement in a supply channel is low. Thus, one can infer that as long as interdependence is low in the supply channel engagement, KEB is retarded irrespective of the level of inter-organizational trust implying that inter-organizational trust has no impact on KEB. Accordingly,

H1: *In a supply channel engagement with low interdependence, knowledge exchange behavior among supply channel partners is retarded irrespective of the state of inter-organizational trust*

H1a: *In a supply channel engagement with low interdependence, knowledge exchange behavior among supply channel partners is retarded when inter-organizational trust is low.*

H1b: *In a supply channel engagement with low interdependence, knowledge exchange behavior among supply channel partners is retarded even when inter-organizational trust is high.*

3.6 Moderate interdependence

The middle of the space of ID (see Figure 3.15) is where both actors are equally but moderately dependent on its partner – the boundary between inter-dependent and not interdependent space with little or no dependence asymmetry. This represents an intermediate condition because the interaction is not dominated by independence where an actor can act largely on its own preference. Nor is an actor sufficiently dependent to be compelled to coordinate with its partner.

A contemporary example might be the relationship that Toyota has with its 'mega' suppliers (e.g. Advics, Magna, Johnson Controls). These suppliers largely develop subsystems (e.g. Advics makes brake system) themselves based on input from Toyota about product-specific proprietary knowledge. The suppliers do have a substantial – although not total – dependence on Toyota because these subsystems are developed specifically for Toyota. However, the main intellectual property (e.g. product design patents, proprietary production processes, etc) is retained by the supplier which enables them to market their products to other customers. Likewise, Toyota can source its subsystems elsewhere but would incur a significant learning cost by switching (e.g. vendor substantiation or in-house development of previously outsourced design work).

3.6.1 Patterns of interdependence

We model this condition by the game shown in Figure 3.22 where each actor has a dependence index midway in the range between independent (DEPx=0.00) and dependent (DEPx=1.0) The actors dependence is DEPa=.58 for column and DEPb=.53 for row . The nature of the relationship is reflected in the task coordination requirements (MBC) where only one actor provides knowledge – in our example the mega-supplier – while the other receives. However, each would prefer that the partner provides knowledge (MFC) while themselves not supplying (BRC). Thus, there are incentive conflicts (BRC and MFC are discordant). The net effect of these conflicts largely counterbalance each other though since the game matrix has almost no non-correspondence (IC ≈ 0; neither goal conflict nor alignment).

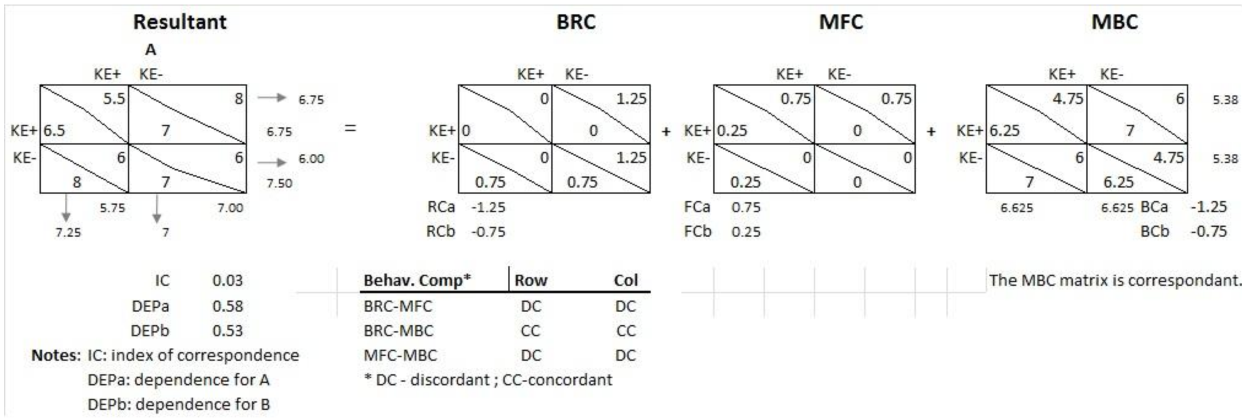

Figure 3.22: Moderate Interdependence

3.6.2 Member-level effects: low IOT

If the firms lack inter-organizational trust – as was characteristic of some domestic car manufacturers with their large suppliers - each member will seek to maximize its own gain. The mega-supplier would be induced to protect its intellectual property while its OEM (original equipment manufacturer) customer would be disinclined to help the supplier with transfers of know-how that can benefit that supplier in its business with rival OEM's.

As shown in the decomposition, each actor's own preference (BRC) is to withhold knowledge while wanting its partner to provide it (MFC). The task coordination requirement (MBC) does not compel either actor to disregard its own preference since its effect on the overall payoff is comparable to the other components as can be observed from the control values of RC FC and BC shown in Figure 3.22.

3.6.3 Dyad-level effects: low IOT

Given low inter-organizational trust, both members tend to act out of individual self-interest; thus, the outcome at the dyad level will be a solution where each member seeks the best achievable individual outcome given that it expects its partner to do the same; here KE- for both yielding a payoff of [7] and [6] for row (B) and column (A) respectively. That is, the row member of the dyad prefers not to provide knowledge to its partner (KE-) observing the opportunity for its best payoff [8] while at the least guaranteed its second best payoff [7]. Self interest precludes the row partner to even consider sharing knowledge because such an action simply eliminates its opportunity for its individual best payoff of [8]. A similar strategy guides the column member (A) also to not provide knowledge to its partner (KE-). Furthermore, neither is inclined to take the risk of sharing knowledge (KE+) with its partner on the premise that since its partner would certainly not share (KE-), there is, after all, no change in its own expected payoff by sharing or not sharing. What if the other follows the same rationale? This is the effect of low inter-organizational trust in this moderately interdependent supply channel engagement.

3.6.4 Member-level effects: high IOT

If, however, the level of inter-organizational trust is high, as in the original example with Toyota, each member would wish to maintain trust with its partner by investing in the relationship. This earns a member the right to continue to enjoy the benefits, which exceed the investment to create trust, of belonging in that relationship. Toyota benefits because its suppliers can solve problems independently and develop new solutions that may have otherwise been unavailable to Toyota or only at added cost. Likewise, the mega-supplier benefits from the knowledge that Toyota shares with it and enables the mega-supplier to increase its knowledge base and serving as a barrier to entry for competitors.

3.6.5 Dyad-level effects: high IOT

Often, maintaining a relationship requires that a member incur some cost. In this example, if row (B) provides knowledge it can only receive its second best outcome of [7] instead of [8] – a cost of 1 to 'invest' in the relationship. But seeking its own best outcome [8] entails its partner (A) settling for a lower payoff - [6] instead of [8] - essentially imposing a penalty of 2 on its partner which would be a disincentive for that partner (column) to continue with a pro-relational orientation. A similar rationale followed by A (the column partner) entails a cost of 2 to "invest" in the relationship while seeking its own best outcome leads to a penalty of 1 on its partner.

Common knowledge of the payoff structure reveals to both members of the dyad that it is impossible for both to realize their highest payoff simultaneously. Also, the high inter-organizational trust prevailing between the two supply channel partners promotes mutual desire to continue the relationship. The best possible investment in the relationship results when row accepts a small cost [-1] in order for the dyad to generate a higher rent [2] which can be appropriated by each member such as to offset the investment in the relationship. In short, a high level of IOT in the supply channel directs the dyad to seek maximization of joint payoff - a relational strategy.

Thus it can be seen that when interdependence between the supply channel partners is moderate, inter-organizational trust does indeed play a role in influencing knowledge exchange behavior. Accordingly,

H2: *In a supply channel engagement with moderate interdependence, knowledge exchange behavior among supply channel partners is contingent on inter-organizational trust.*

H2a: *In a supply channel engagement with moderate interdependence, knowledge exchange behavior among supply channel partners is retarded when inter-organizational trust is low.*

H2b: *In a supply channel engagement with moderate interdependence, knowledge exchange behavior among supply channel partners is attenuated (transmissive) even when inter-organizational trust is high.*

3.7 High interdependence

The level of interdependence is high when both members have a high dependence on each other – as in the vicinity of point B in the space of ID (see Figure 3.15); both members' outcome is strongly influenced by the action of its partner. Such an environment supplants the role of an actor's own preference and is instead dominated by the nature of the task coordination requirements. These external conditions impose a cost on each actor if one, or both, do not properly coordinate their actions.

A possible example might be the case of Tesla Motors and Panasonic collaborating on the 'Giga-factory' to develop battery modules for electric vehicles. The technical and economic viability of an electric vehicle is strongly influenced by the technical capabilities of its battery system which must be optimized for a specific application. In turn, high volume large capacity battery manufacturing is technologically challenging and financially risky because of the specialized market for the battery. The vehicle/battery combination are highly interdependent because they are being co-developed. A change in one platform (eg. battery production capacity or vehicle demand forecast) would have a strong effect on the other and could result in wasteful rework if not properly coordinated by both partners.

3.7.1 Patterns of interdependence

We model this condition by the game shown in Figure 3.23 where each actor has a dependence index approaching 1.0 (maximum dependence). The relationship is dominated by the MBC component (coordination requirement) since the majority of the resultant payoff originates from the MBC component which, in this case, is *not* correspondent. That is, A (Column member of the dyad) would like B (Row member) to share knowledge (KE+) whenever A chooses to share (KE+) and wants B to not share knowledge (KE-) whenever A chooses to not share (KE-). On the contrary, B would like to not share knowledge (KE-) whenever A chooses to share knowledge (KE+) and vice versa and hence the non-correspondence in MBC. This effect is reflected in the resultant matrix by the absence of a nash equilibrium. Both the actor's own preference (BRC) and what it prefers of its partner (MFC) play a minor role in the relationship as reflected in the control values of RC and FC in comparison with BC (see Figure 26). In effect, this environment is akin to the sport of 'logrolling' where each player is forced to cooperate with the other player so that they both can pass over the log without falling off.

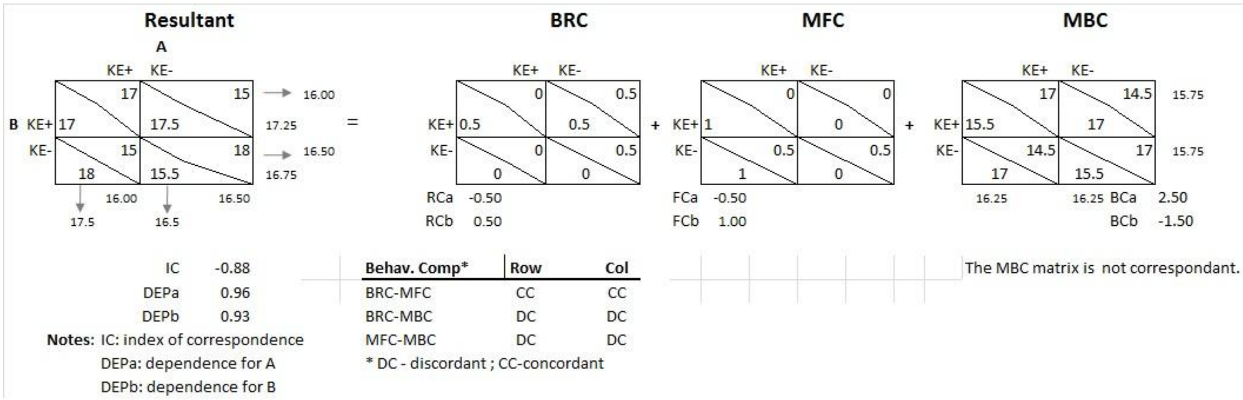

Figure 3.23: High Interdependence

3.7.2 Member-level effects: low IOT

When inter-organization trust is low, each member of the dyad will tend to seek its own best outcome based on its expectation that its partner ought to have a similar motivation. In the game depicted, row might not want to share knowledge (KE-) since its best payoff [18] can only occur by this action. Yet row knows that column will not play into this move by choosing to share knowledge (KE+) which would be against that members own best interest by settling for a payoff of [15] if it chose (KE+) instead of a payoff of [18] which it could get by choosing to withhold knowledge (KE-). Thus, row knows that trying to get its maximum best payoff of [18] would be futile. Indeed, row runs the risk of getting its worst payoff of [15.5] under this strategy. Thus, row would choose to minimize its loss potential by choosing (KE+) and avoid the possibility of getting its worst payoff. A similar strategy guides the column member to gravitate towards knowledge sharing (KE+). In the absence of trust both members seek to minimize its loss potential by sharing knowledge and foregoing its best outcome while also avoiding the risk of its worst outcome.

3.7.3 Dyad-level effects: low IOT

Given low inter-organizational trust, both members tend to act out of individual self-interest. In the case of high interdependence, however, each member is strongly affected by the action of its partner. As explained in the previous section, each member knows that it cannot obtain its individual best payoff of [18] because that would require its partner to act irrationally given a low IOT condition.

The majority of the payoffs in the resultant matrix arise from the task coordination requirements (MBC). This coordination is not without cost because, as clarified earlier, MBC is not correspondent. A non-correspondent MBC component means that coordination has a cost. The cost of coordination will be compensated for by the contributions from the other components as is the case in high interdependence . For example, if the row member were to withhold knowledge (KE-) to try and get [17] from the MBC, its partner can be expected to do the same resulting in row getting a payoff of only [15.5]. If column seeks to withhold knowledge (KE-) for its best payoff of [18], since its partner can be expected to share (KE+) (see Figure 3.23) it entails a significant cost to column - most of it an MBC contribution of [14.5] instead of [17]. Each coordination possibility (the four cells in the MBC) impose a cost on one or the other member in the dyad. The cost of coordination can be minimized to [1.5] if both provide knowledge to each other or both don't (top left or bottom right cell in the MBC component). However, the effects of BRC and MFC, though relatively mild, renders the top left cell to be the least cost alternative in the resultant matrix.

By both sharing knowledge (KE+) each also picks up a contribution from the MFC (1.0 for row and .5 for column) - both want to receive knowledge and can only get it by contributing knowledge to the relationship.

In short, common knowledge of the payoff structure reveals to both members of the dyad that neither can expect to reap its respective best payoff. Self interest, then, steers both to seek to minimize its loss potential. The only way both members can be sure of avoiding their respective worst payoff is by both sharing knowledge (KE+, KE+). Thus, the dyad assumes a trade-like stance where an expectation of reciprocity makes cooperation, even at a cost, preferable to non-cooperation. This is the effect of low IOT in a highly interdependent supply channel engagement - i.e. share knowledge notwithstanding poor inter-organizational trust !

It should be noted that while the cost of [1] to each member appears to exceed the rent of [.5], the alternative to cooperation would be less beneficial for both members. This game has no stable game-theoretic equilibrium (individual maximizing solution) because neither member has a dominant strategy that enables it to always achieve its best outcome without consideration to its partners response. For example, for if row withheld knowledge then column would do likewise resulting in row getting 15.5 (its worst payoff at a cost of 2.5 to itself) while column gets 18 (its best). Likewise if the actions are reversed column would lose 3 and reap its worst payoff of 15. Thus, the investment of 1 by each member is a ‘cost avoidance’ strategy rather than seeking the next best payoff.

3.7.4 Member-level effects: high IOT

When interorganizational trust is high, each member seeks to maintain faith with its partner to preserve the benefits of a trusting relationship by not imposing an undue cost on its partner. Whereas in the low IOT case each member sought to minimize its own loss potential based on what it expects its partner to do, when IOT is high each member seeks to 'do no harm' to its partner in order to not violate the prevailing mutual trust.

Examining the resultant matrix from the perspective of row: if it chooses (KE-), it would be 'asking' its partner to give up 3 points in its payoff (from 18 to 15 by choosing KE+) – in effect costing its partner for selfish gain and making the relationship less attractive to its partner. Also, what if the partner entertains the same thought process and chooses (KE-) ? Both violate the prevailing trust; in fact, the row member suffers the consequence by losing 2.5 points in its payoff (from 18 to 15.5 having chosen KE-). More importantly the relationship nurtured by high IOT is compromised.

If, however, row chooses (KE+),its partner would only lose 1 point from its best payoff (from 18 to 17 by choosing KE+). In other words, row has to sacrifice 1 point from its best payoff of [18] so that its partner does not suffer a 3 point loss. In fact, now, both members pay an equal cost [1] - the price paid by both to nurture the relationship. A similar strategy guides the column member to gravitate towards knowledge sharing (KE+).

3.7.5 Dyad-level effects: high IOT

As was discussed earlier in section 3.6.5, maintaining a relationship may entail one or both members incurring some cost - the price paid to nurture the relationship in the supply channel. In this example, if row (B) provides knowledge it can only receive its second best outcome of [17] instead of [18] – a cost of 1 to 'invest' in the relationship. But seeking its own best outcome entails its partner (A) settling for a lower payoff essentially imposing a penalty of 2 on its partner which would be a disincentive for that partner (column) to continue with a pro-relational orientation. A similar rationale followed by A (the column partner) entails a cost of 2 to "invest" in the relationship while seeking its own best outcome leads to a penalty of 1 on its partner. If both members choose (KE+) and incurred a cost of 1 point each (upper left cell) the joint payoff is maximized (17+17 = 34) which is higher than if each member sought its individual maximum outcome, the lower right cell, with a joint payoff of 33.5 (15.5 + 18).

The high inter-organizational trust prevailing between the two supply channel partners tends to promote mutual desire to continue the relationship. Common knowledge of the payoff structure reveals to both members of the dyad that it is impossible for both to realize their highest payoff simultaneously.The best possible investment in the relationship results when both row and column accept a cost [1] in order to maximize the joint payoff for the dyad even when the rent generated by this relational strategy [.5] is less than the cost assumed by both partners - a net loss for both members of the dyad. Unfortunately, no other alternative is superior from a dyadic perspective - thus, a real cost to both partners to nurture the supply channel relationship. This is the effect of high IOT.

Observe that the game theory solution (low IOT) and the knowledge sharing strategy based on the relational view (high IOT) happen to be the same (KEB promoted) when interdependence is high essentially indicates that IOT is irrelevant when the interdependence within a supply channel is high. Thus, one can infer that as long as interdependence is high in the supply channel engagement, KEB is promoted irrespective of the level of inter-organizational trust implying that inter-organizational trust has no effect on KEB.

Accordingly,

H3: *.In a supply channel engagement with high interdependence, knowledge exchange behavior among supply channel partners is promoted irrespective of the state of inter-organizational trust*

H3a: *In a supply channel engagement with high interdependence, knowledge exchange behavior among supply channel partners is promoted even when inter-organizational trust is low.*

H3b: *In a supply channel engagement with high interdependence, knowledge exchange behavior among supply channel partners is promoted when inter-organizational trust is high.*

It is noteworthy that when interdependence is high KEB is expected to be promoted despite the irrelevance of inter-organizational trust in this environment. Likewise, even when interdependence is low, the role of inter-organizational trust in influencing KEB is irrelevant (see section 3.5); only, in this case, KEB is expected to be retarded.

3.8 High Dependence Asymmetry

The hypotheses so far have been focusing on interdependence based exclusively on joint dependence. The other dimension of interdependence, viz., dependence asymmetry was held constant at near zero - i.e., no or insignificant dependence asymmetry in the dyad. Now, we consider the case where the members in the dyad have different levels of dependence on the relationship. The extreme case is for one actor to have near total dependence on its partner who is almost independent– the case of unilateral dependence - segment A-a in the space of ID (see Figure 3.15). Dependence asymmetry creates a power imbalance between the partners which increases the potential for conflict in the dyad (Bucklin, & Sengupta,1993; Kumar, Scheer & Steenkamp,1995).

In our model this occurs because the less dependent actor may have readily available alternatives and hence low exit costs or it simply has a better cost structure compared to its partner. The more dependent partner may have very poor alternatives to the relationship and thus is trapped.

It is not inevitable that a stronger partner exploit its more dependent partner though. The more dependent partner could engage in mitigating actions which reduces the benefit of exploitation or if need be, even exit the relationship altogether. How the independent actor behaves would be a reflection of whether it has a long or short-term orientation towards its partner.

For instance, we might revisit the Toyota example (see section 3.6) except this time considering its relationships with its small suppliers in place of its mega-suppliers. Specifically, Toyota is the dominant partner in most (or all) its buyer-supplier relationships yet it builds deep supplier relationships. The Japanese concept of *Keiretsu* is based on the idea of a network of small to medium sized enterprises acting toward a shared objective under the benevolent influence of a powerful firm like Toyota. The small firms benefit from this kind of 'patronage' while the powerful firm benefits from the network of individually weak firms acting collectively on behalf of its goals.

In contrast, some automobile manufacturers have historically been very exploitive of their small suppliers using its purchasing volume as leverage to extract concessions.

3.8.1 Patterns of interdependence

The game shown in Figure 3.24 models a relationship with high dependence asymmetry. Member A (column) has a dependence index of .18 on a range of 0 (no dependence) to 1.0 (total dependence). The row actor has a dependence of .96 – near total dependence on the relationship. For the row member of the dyad, its BRC component value is three times less powerful than that of its partner - the column member - as can be seen by the individual elements of the BRC matrix. In addition, row is far more influenced by columns actions than vice versa (see MFC matrix). The MBC matrix (task coordination) is not correspondent thus coordination would impose a cost on one or the other member.

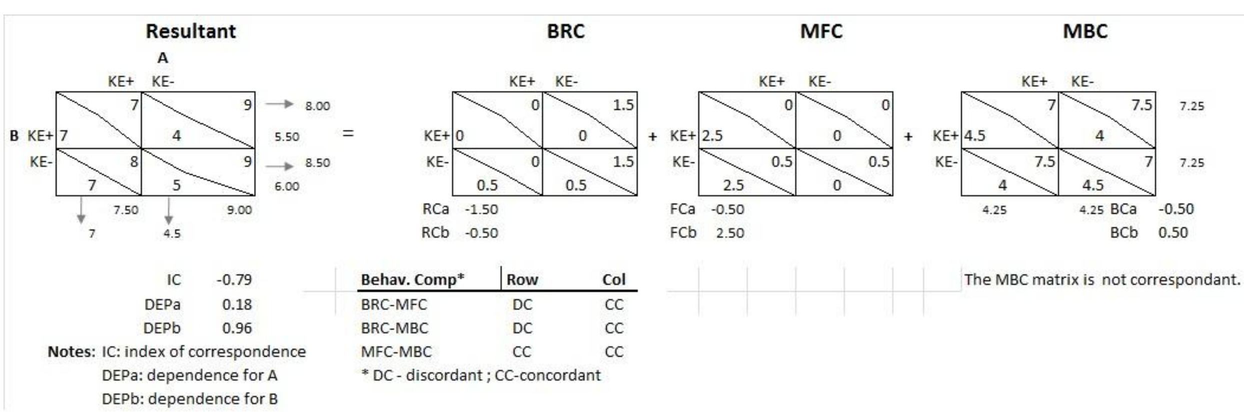

Figure 3.24: High Dependence Asymmetry

3.8.2 Member-level effects: low IOT

If there is little or no inter-organizational trust each member will be expected to act in its own immediate best interest. The column member of the dyad (A), then, seeks to withhold knowledge (KE-) because by that action it gets its best payoff of [9] irrespective of how row responds. This is because column's BRC is dominant as reflected by the higher control value for RCa relative to FCa and FCb. Column member is not susceptible to the actions of its partner either as seen in the very minor MFC contribution to its resultant payoff (only a fifth of its partner). The BRC-MBC concordance for the column member only reinforces the dominance of BRC's contribution to the resultant matrix for the column despite the low level of MBC's contribution to the resultant matrix.

The row member (B), being heavily dependent on this supply channel engagement (DEPb = 0.96), is only able to seek to minimize the loss in its payoff by choosing to not share knowledge (KE-). In contrast, for the column member (A) the biggest change to its resulting payoff is the result of its own actions - i.e., Column (A) through its own preference (BRC) can augment its resultant payoff by [1.5] vs. only [.5] for its dependant partner (see Figure 3.24). Additionally, A can at most lose [.5] from either its MFC if its partner (B) acted irrationally by choosing (KE+) which is against column's preference *or* [.5] from the MBC if row chose (KE-) per its own preference. Thus,if column stood pat (KE-) at worst it would lose either [.5] from its MFC or MBC but not both. That is why column's achieves its best resultant payoff by selecting (KE-) irrespective of what its dependant partner does.

3.8.3 Dyad-level effects: low IOT

Given low inter-organizational trust, both members of the dyad tend to act out of individual self-interest; thus, the outcome at the dyad level will be a solution where each member seeks the best achievable individual outcome given that it expects its partner to do the same; here KE- for both yielding a payoff of [5] and [9] for row (B) and column (A) respectively - the Nash equilibrium which is the bottom right cell. For the dyad, the BRC component of the less dependant member (column) prevails on both because the column member is free to act on its preferences while its more dependant partner (row member) has little choice in the matter. Indeed, the dependant actor strongly prefers to receive knowledge while not providing any in return consistent with its dependant status as reflected in the MFC component.

For the column member the choice of not providing knowledge to its partner (KE-) is a no-brainer since its best payoff [9] is assured by this strategy. The dependence asymmetry in this engagement is very clear in that the row member of the dyad (A) is literally helpless and self interest directs it to 'run for cover' - i.e., minimize its loss - by not sharing knowledge (KE-) since its preference to receive knowledge from B (column) cannot fructify; self interest precludes the column partner to even consider sharing knowledge because such an action not only eliminates its opportunity for its individual best payoff of [9], but also renders it vulnerable to reap its worst payoff of [7]. In essence, since both members of the dyad prefer to not share knowledge {KE-, KE-}, KEB in the dyad is expected to be 'retarded' - the effect of low inter-organizational trust.

3.8.4 Member-level effects: high IOT

If, however, inter-organizational trust between the members is high (e.g., a keiretsu-like relationship), then, A (column), the more independant member, can be expected to be motivated to use its dominant position in this engagement for nourishing the prevalent mutual trust in the dyad. Clearly, the column member alone has the wherewithal to facilitate and preserve the cooperative spirit in the dyad; self interested behavior on the part of the column member (A) will prove detrimental to the prevailing trusting relationship. The motivation for A, the relatively independent member of the dyad, to forego exploitive behavior towards its more dependant partner can arise from various sources including familial, cultural or long term commercial interests. Moreover, it is quite possible that the independent actor's relative dominance in the dyad may be idiosyncratic to this relationship and not easily replicable in alternative arrangements; as a consequence, self interest of the dominant member, A, may encourage it to act in such a way as to nourish this particular relationship. Thus, seeking the sustenance of a long term relationship in the dyad, the column member (A) will be inclined to share knowledge as desired by the row member (see the MFC component in Figure 3.24) risking a worst-case-scenario cost of 2 in its payoff [9 - 7].

Observe that if the column member (A) is expected to share knowledge (KE+), then technically the row member ought to be indifferent to its choice of KE+ or KE- since it is assured its best payoff in either case. However, row (B), the dependent member in this dyad, expecting its partner to show goodwill by sacrificing its best payoff, can be expected to signal its willingness to reciprocate cooperative behavior on its part by seeking to minimize colum's cost; hence its choice of KE-. In fact, KE- is also a safer choice for the row member because it eliminates the risk of worst payoff [4] for the row member if, by chance, the column member deliberately or inadvertently decide to not share knowledge (KE-).

3.8.5 Dyad-level effects: high IOT

The nature of the relationship between the members of the dyad depends on the independant member's (column) orientation; short-term vs. long-term. In the low IOT environment, as discussed in section 3.8.3, the dependent member is unable to achieve its best outcome (payoff of 7) and instead has to settle for its second best/worst outcome of [5] - a cost of 2. And, the dominant member of this dyad runs the risk of potential conflict and aversive behavior from the weaker member (row) as it seeks to combat the effects of exploitation.

In the high IOT condition, since the independent member (Column) is inclined to invest in the relation by sharing knowledge (KE+) and not seeking any from its partner which happens to be precisely the row's preference, the dyad is able to achieve maximization of joint payoff (bottom left cell in the resultant matrix in Figure 3.24) - a relational solution for the asymmetric dependence condition in the dyad. While this solution generates a relational rent of [1], it happens at the expense of the column member compromising for its second best payoff [8] - a loss of 1. The rent of [1] could possibly be used as a compensation for the investment by the column member. Even if the rent is equally appropriated within the dyad, to the independent actor the long run value of goodwill (social capital) is expected to exceed the short-term payoff from the exploitation of its vulnerable partner. This is the effect of high IOT on the dyad. Since only one of the partners contributes knowledge to the relationship, the KEB is said to be attenuated.

Thus, it can be seen that when dependence asymmetry between the supply channel partners is high, inter-organizational trust does play a role in influencing knowledge exchange behavior. Accordingly;

H4: *In a supply channel engagement with high dependent asymmetry, knowledge exchange behavior among supply channel partners is contingent on inter-organizational trust.*

H4a: *In a supply channel engagement with high dependence asymmetry, knowledge exchange behavior among supply channel partners is retarded when inter-organizational trust is low.*

H4b: *In a supply channel engagement with high dependence asymmetry, knowledge exchange behavior among supply channel partners is attenuated (absorptive) even when inter-organizational trust is high.*

4. Method

A lab experiment was employed to test the hypotheses. In selecting a lab experiment over the alternatives a tradeoff is made among realism, generalizability and precision, what McGrath (1981) called the 'three horned dilemma'. Realism relates to how authentic the participant feels the environment to be. This is maximized in a field study because the participant is in his or her actual environment. Generalizability refers to how findings can be applied to a context outside the research domain. Again, field studies are better positioned for this consideration since participants are operating in their actual environment. However, field studies pay for these benefits by their inability to control for the contextual variables. Lab experiments are capable of controlling for the assumptions behind the theory, non-theoretical variables and for systematic manipulation of theoretical variables (Umanath, Ray & Campbell, 1993).

The skepticism toward lab experiments arises from its perceived loss of realism and generalizability, the trade-off that McGrath described. The skepticism towards experiment and its external validity misunderstands the intent of a lab experiment. A research method is sought for one of two distinct focuses: effects application or theory application (Calder, Phillips & Tybaut, 1981). *Effects application* attempts to produce a high fidelity recreation of the real world context and demonstrate the effect. This means that the lab environment must be *real* from the participant's perspective. This is a very challenging requirement and may account for much of the concern about generalizability. However, a lab experiment is better suited for theory application (Calder et al, 1981). *Theory application* is used to test the status of the theory; it is the law like relations that are being tested - not the specific effect (Calder et al, 1981) - basically attempting to 'break the theory (Mook, 1983).

Thus, to summarize the justification for the selection of a lab experiment for this research we present a synopsis presented in Umanath et al (1993, p36) where the intent of a lab experiment is further elaborated. The Calder et al/Lynch debate that Umanath et al (1993) are referring to was a series of articles debating the merits and shortcomings of a lab experiment and is a useful clarification of our intent in this section.

"Generality (external validity) in this case results from the effects observed assessing the theory, and the theory in turn assuming the burden of explaining events beyond the research setting, as opposed to mapping observed effects directly into events beyond the research setting as in a field study (Calder, Phillips, and Tybout 1981). McGrath and Brinberg (1983), analyzing the Calder et al./Lynch debate on external validity, conclude that most of the apparent disagreements between the two become moot when viewed in the light of the broader research context rather than a given single study. According to them, a particular focal problem must get sufficient attention and exploration in terms of all the different research approaches, so that the research community can increase its confidence about the findings and their meanings (p. 123). Hogarth (1986, p. 446) clarifies the complementary nature of internal and external validities by asserting the need for "going from highly controlled laboratory conditions to quite 'loose' field studies" as a part of a scientific program of research."

Using this perspective, if a phenomenon is observed in a lab context then it is expected to happen in 'the real world' if those conditions are ever encountered. It is then the role of theory to explain '***why***' (Mook, 1983). In keeping with Hogarth's (1986) observation, while this work is predicated on a lab experiment, plans are under way to follow up in the future with a field study as part of a program of research in this domain.

4.1 Experimental Design

While a supply channel relationship is understood to be of an indefinite duration - in contrast to one-time market purchases – the experiment used a one-time interaction intended to evaluate the decision to enter into a knowledge sharing relationship. A repeated trials game had originally been intended; however, the dissertation committee felt that this would introduce unintended consequences (e.g. evolution of trust, learning effects, etc.) not characterized in the hypothesis development. A compensatory mechanism to sensitize the participants to past partner behaviors was incorporated in the experiment; please see section 4.4 for details.

Dependence asymmetry and joint dependence[8] are derived variables; it is the individual actor's dependence in the dyadic relationship that was manipulated in the experiment. Knowledge complementarity is a state variable and was held constant at high KC in the experiment. The dependent variable was knowledge exchange behavior (KEB). The simplest way to measure KEB was to have each participant answer the following question after each scenario that was played "In this scenario, will your decision be to share know-how with your partner?" using a six point Likert scale. Other items on the user interface captured other aspects of a participant's response (e.g. perceptions of dependence, perception of task coordination requirements, etc.) and will be detailed in the section describing the simulation software.

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[8] Joint dependence = DEPa + DEPb (range: 0-2)
Dependence asymmetry = |DEPa – DEPb| (range: 0-1)

The table below shows the factors and levels for each hypothesis.

Table 4.1: Summary of Factor Levels

	Low JD No DA	**Moderate JD no DA**	**High JD No DA**	**Low JD Max. DA**	
Loc. In ID space	Vicinity of pt. A	Midpoint of segment A-B	Vicinity of pt. B	Segment A-a	Class of game
Low Trust	**H1a** KEB retarded	**H2a** KEB retarded	**H3a** KEB promoted	**H4a** KEB retarded	Variations of PD, Threat-vulnerable and Force-vulnerable
High Trust	**H1b** KEB retarded	**H2b** KEB attenuated	**H3b** KEB promoted	**H4b** KEB attenuated	Variations of Stag game

4.2 Participant Selection

Participants were recruited to play a business simulation game where each played the role of a decision maker in a fictitious supply channel. The participant had to decide if their firm should provide valuable know-how to a partner firm given the information provided in the simulation scenario. The participants came from two sites. The first site consisted of undergraduate students from a major Midwestern University in the operations management program who were enrolled in a project management course. As part of the project management class, a supply chain case was used as the course capstone; as a consequence, the participants in the experiment were sensitized to a supply chain context. The second site was at a major

Southern University and consisted primarily of undergraduate seniors majoring in operations management enrolled in a capstone supply chain strategy course. The participation incentives and confidentiality conditions are described in the original approved IRB protocol 11091203[9].

4.3 Test Procedure

Once participants were recruited, advised of their right to not participate, and confidentiality (see IRB protocol for details), they were then briefed on the intent of their participation and the simulation system mechanics. The following general steps were followed:

1) Participant registration

   The participants created individual user accounts in the simulation system, which included entering their own participant identification number and password, and answering demographics type questions in a short survey.

2) Briefing

   The aim of the research was described and the sequence of events in the session explained. Participants were then informed that they would be role acting a decision maker in a supply channel and will be given a business case explaining what their individual goals are and the business environment. The software was then shown along with a demonstration of how it runs.

3) Pre-test training

[9] Appendix G

Participants were then walked through a mock run of a couple of complete games different from the experimental context to gain familiarity with the system. Questions were then answered as the training proceeded.

4) The experiment

After the participants were familiarized with the simulation software, the actual experiment started. All sessions were predefined in the simulation software.

5) Administering the experiment

Each subject played eight games with each game representing a distinct treatment. The sequence of eight games took approximately an hour to complete.

6) Post-game

At the end of each game, every participant answered a brief survey assessing his/her perception of the treatments experienced in the game.

4.4 Simulation Software

The purpose of the business simulation game was to create a realistic yet easily understandable business situation that mimics a supply channel involving knowledge exchange and where the participants must seek an optimal solution for their respective firms. The scenarios were meant to create a context that represents situations involving different incentive structures. However, the theoretical underpinnings of the scenario were not inferable by the participants to prevent response bias. This was accomplished by randomizing the sequence of presentation of the game matrices; in addition, randomization prevents learning effects.

The participants were briefed on the scenario and their roles. Each participant played eight scenarios, a combination of high and low inter-organizational trust – four original game matrices, four scaled transposes with the same ordinality as the original. A transposed game matrix produces the effect of an actor playing the role of his or her partner since the transpose is a transformation of the game matrix where a column's payoff is substituted for the row and vice versa. Note that the hypothesized effects are at the dyadic level. Thus, when each participant played the role of a member in the dyad (say row) in a scenario (game) and later play the role of the partner (column) in the same scenario, the pooled response provides the dyadic effect. Here, the second role was unobtrusively induced in the transpose matrix by randomizing the presentation of the scenarios for every participant such that there was no sequence of related games (e.g. like H1 being immediately followed by its transpose game) and also by scaling the payoff values. In effect, any cognitive and/or personality differences in a dyad made of two different participants was eliminated.

A survey followed each scenario for the participant to answer. The items related to trust, knowledge sharing intentions, and perceptions of the behavioral components (i.e. BRC, MFC and MBC) for that scenario.

4.5 Post-game Survey

After the test sequence there was a short survey to assess the extent of inducement of the research variables. Questions related to the impressions the participants developed from the game narratives and primarily relate to perceptions of trust in their partners intentions.

4.6 Pilot Test

The original research proposal defense was held in March 2013, a week before a scheduled trip to Yonsei University in Korea to collect data. In pre-trip testing, with a small group of MS-IS students, it was observed that 12 games were too taxing for most test participants; so, the sequence was reduced to eight by incorporating the four scaled matrices into the matrix transposes. There is no loss in empirical validity since scaling game matrices does not alter any of the characteristics of the payoff structure (see Rapoport, 1967).

At Yonsei University two lab sessions were held – one on April 10th and another on the 11th - with 39 participants each playing eight scenarios. The original intent of data collection was considered premature. Instead the intent was shifted to an extensive pilot study since a major revision from a repeated trials experiment to a single trial experiment was adopted based on the feedback from the dissertation committee. The goal was to validate the single trial test procedure and the software under actual test conditions using typical expected sample sizes. During the two sessions and the debrief that followed, it was learned:

1.) Eight games is the limit for most users.

    It was unanimously confirmed that 12 scenarios would have been too many for sustained concentration in one session.

2.) The scenarios were hard to relate to for a one-time decision.

    There was no historical narrative to which participants could relate to for current decision making. This lack of history resulted in most users 'playing it safe' by pursuing a best individual payoff – a game theoretic solution. As one participant stated, "so my decision [sp] safe score.". This resulted in credible game play for the low trust games but not the case for high trust games where pro-relational solutions were hypothesized based on SET (maximizing joint payoff and minimizing payoff differences).

3.) The payoff table (example below) was redundant. The story and payoff matrix were sufficient.

Your Action	Bob's Action	Your Points	Bob's Points
Confess	Confess	-3	-3
Confess	Not confess	-1	-5
Not confess	Confess	-5	-1
Not confess	Not confess	-2	-2

Figure 4.1: Payoff Table

4.) Some were unsure of which firm of the two in the story they were supposed to be playing (i.e. row or column).

5.) Training was too long.

The original training took close to an hour and had an expansive introduction to the experimental scenarios. It was learned that a generic, but small scoped, focused examples ought to be sufficient.

6.) No indication on how well they did - some feedback on performance could have helped.

Many participants felt that they had no feel for how well they were doing. In a second pilot run in Cincinnati, the participants (displaced professionals in the B2B outreach group) conveyed similar sentiments.

4.7 Revised simulation software

To incorporate the lessons learned from the Yonsei University and B2B pilot runs significant revisions to the experiment were made. First, while the original simulation software developed by the two MS-IS students worked without any serious issues, it was found to be too complex for the single trial conditions now being used. Also, deployment and access outside of UC (e.g. security) posed major administrative hurdles.

Thus, a complete rewrite of the simulation software for a single trial experiment was undertaken. The software written in Visual Basic for Applications (VBA) by the researcher was extensively tested by one of the dissertation committee members using additional subjects from a different group of B2B members and certified to work flawlessly.

Based on the committee feedback and the experience from the pilot runs, the following changes were made (screens not shown in run order)

1.) A new **scenario information screen** (below) was developed.

   a. The payoff table was replaced by a constructed timeline. Constructed histories have been used in strategy research to reduce personal qualities from contaminating the effects of the situation participants are supposed to be acting in (cf Oskamp, 1971). In this work, the timeline has a very focused purpose. That is, to give participants a feeling of how past interactions between the partners transpired.

b. Error-tolerant programing. Since web connectivity is no longer required the application runs on local machines. Further, common errors (i.e. skipping required fields, special characters, etc.) no longer resulted in application crashes. Moreover, external IT support for the application was no longer required.

c. Intuitive screen presentation. Participants only see scenario information as it becomes appropriate to that stage of the game play

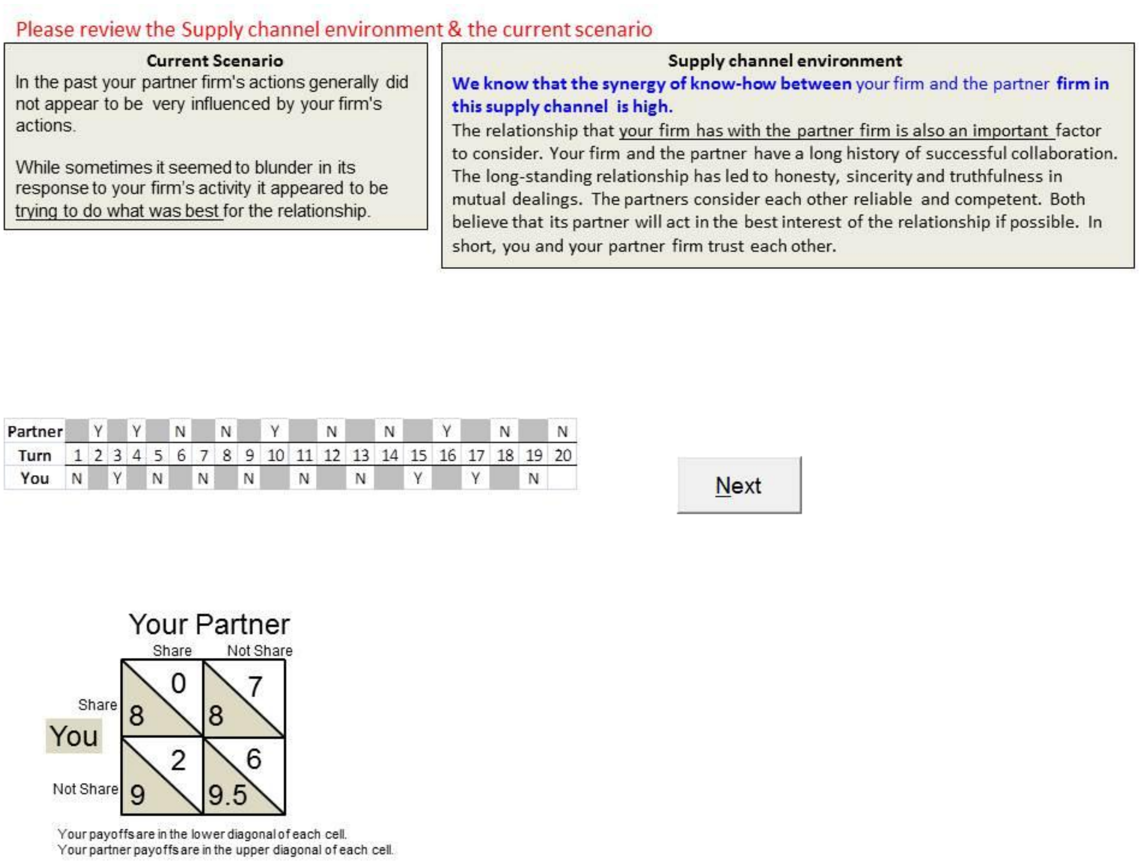

Figure 4.2: Scenario Information Screen

2.) **Post-scenario screens**: In the original version of the software after each scenario a 'performance screen' would indicate a level of achievement for that scenario. This was in response to comments from the debrief sessions that participants felt a need to know how they were doing. In later reviews by this committee it was felt that the original evaluative feedback could lead to respondent bias.

To address the concern of response bias a new post-scenario screen was deployed for data collection. These screens ask the participant a question regarding a fact from each scenario. For example, the participant may be asked to comment on an aspect of the 'Supply channel environment'. Later questions will ask about other facts contained in the narrative. These questions are meant to encourage the participant to read the scenario. No evaluation will be provided.

3.) **Scenario response survey**. The following screen was used by the participants to answer questions after each scenario and this is the instrument that was used to collect the experimental data (i.e. share knowledge, perceptions of BRC, MFC, MBC, trust, etc.).

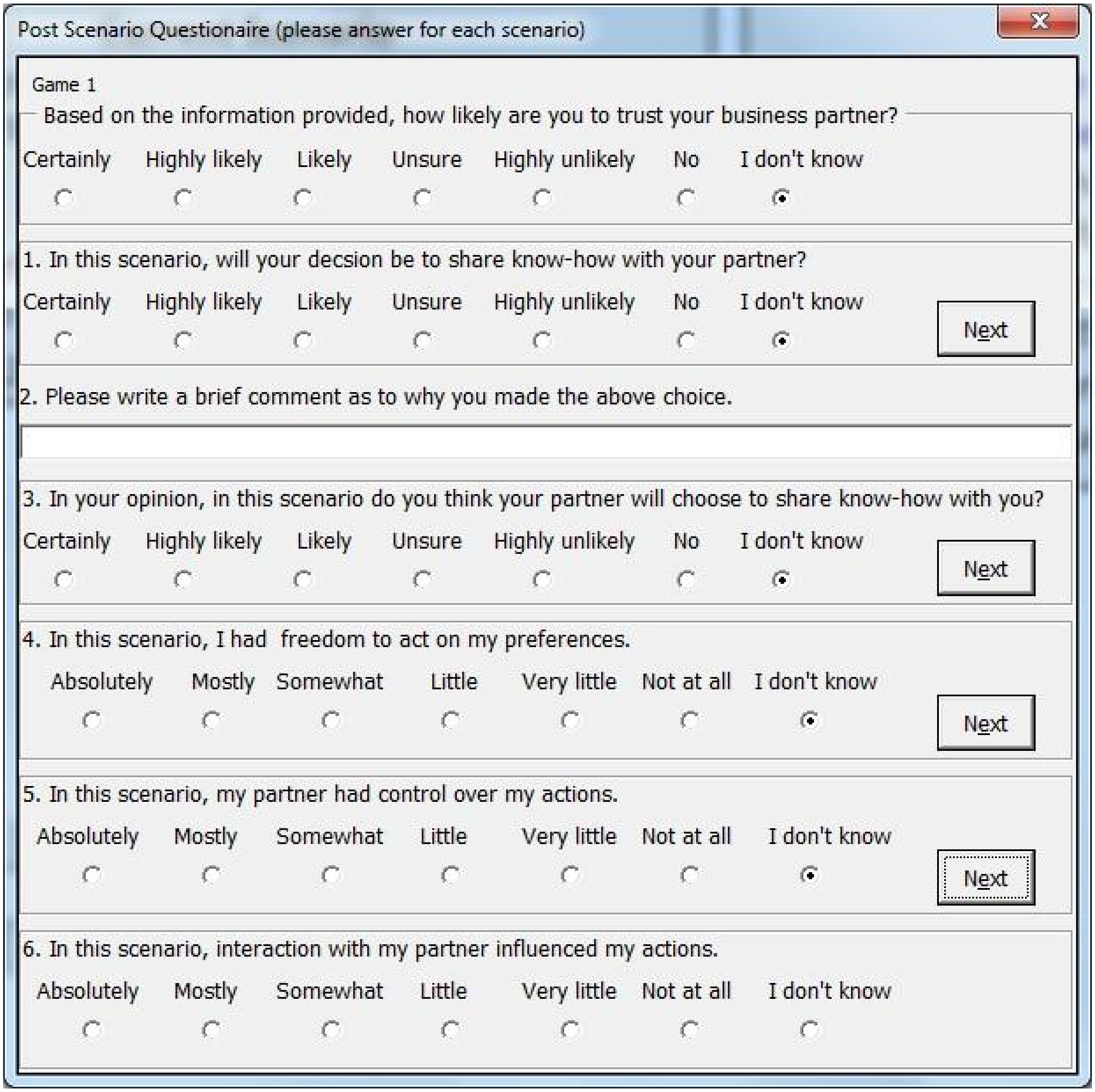

Figure 4.3: Post Scenario Questionnaire

Items 4, 5 and 6 were informed by suggestions from the committee that since the behavioral components (BRC, MFC and MBC) are important theoretical constructs the survey should capture participant perceptions of these. For example item 4 relates to how independent a participant felt – bilateral reflexive control (BRC). Item 5 was for MFC and item 6 was for MBC. From these ID could be calculated (see Appendix A).

4.8 Analysis

4.8.1 Spanning levels of analysis: knowledge exchange as a response vector

The focal phenomenon, knowledge exchange behavior, and the associated hypotheses are defined at the dyad level. However, as explained in the theory section, the dyadic response is composed of individual level responses. This is also reflected in the experimental procedure where a test participant plays both members of a supply channel dyad by playing a game matrix and also its scaled transpose. Therefore, the analysis spans two levels. Analyzing the data at an individual level of analysis requires no additional conceptual development and therefore will be discussed in an abbreviated form. The linkage between levels of analysis follows below.

Knowledge exchange (KEB) in a supply channel dyad consists of the paired responses of each member and is characterized as: promote (both share), retard (neither share) and attenuate (one way sharing). To make use of familiar univariate methods it is necessary to have a single dependent variable that is consistent with the theoretical basis. This can be done by representing KEB as a *response vector* using the mean-centered individual member knowledge sharing responses as components. Since vectors have both a magnitude and a direction, these can be used to represent different aspects of knowledge exchange behavior: (1) the type of KEB behavior (e.g. promote) and (2) the strength of the response.

Figure 4.4 shows the KEB as a response vector and the mapping of the four quadrants of a mean-centered rectangular coordinate system and KEB responses. The KEB response vector *angle* represents how the dyad exchanges knowledge.

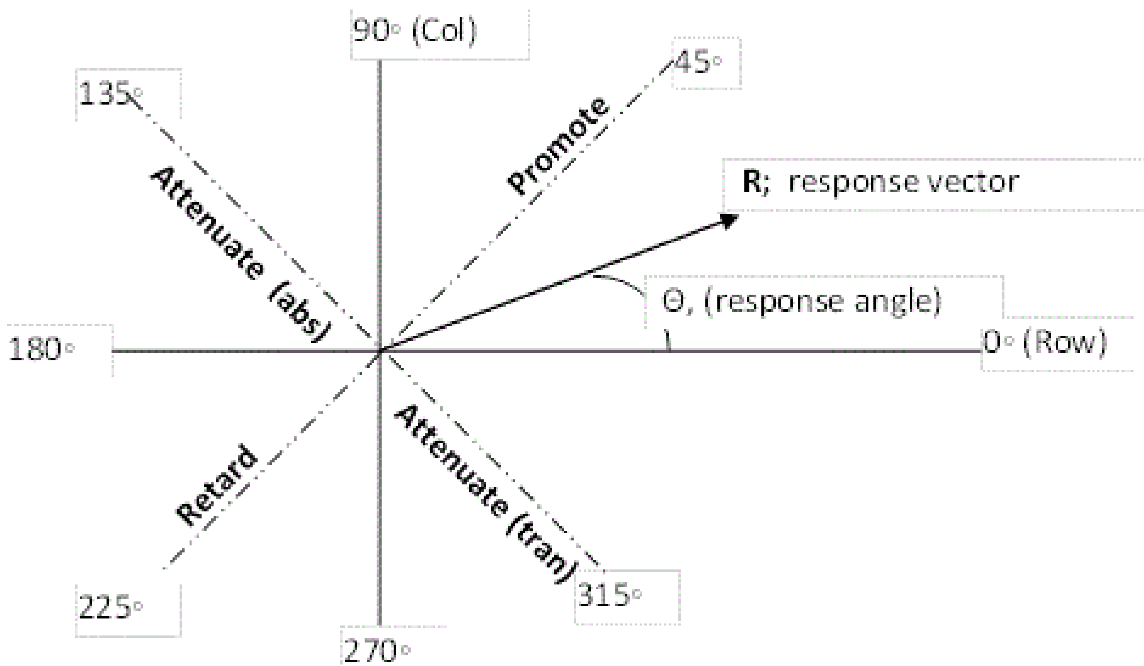

Figure 4.4: The Knowledge Exchange Response Vector

The centerline of the quadrants represent the response-perfect angle for that quadrant. For example, if both the row and column components were equal then the angle would be 45° - KEB promote. If the response angle is not on the centerline but still in the quadrant (e.g. promote is between 0° and 90°), it is still characterized as the KEB response mapped to that quadrant. What this represents is an actor-dominant response. For example, a response between 0° and 45° would be a row-dominant KEB promote – an asymmetric KEB response[10].

[10] The implications of asymmetric KEB are not in the scope of this research because the concept of KEB would have to be extended beyond the current definition. This is an intriguing extension of this research direction since by using a vector representation of KEB – as is done here - there

To construct a response vector the participant responses generated during the experiment are paired for each game (the game matrix and its scaled transpose) using participant ID and the hypothesis number as links. Shown below (Table 4.2) is a variable list followed by an excerpt of the data for three participants.

Table 4.2: Variable List

Name	Description[+]
ID	Participant ID.
HypoNum	Hypothesis being tested.
rQ1	Raw response when playing row (6-point Likert scale, 6 is maximum).
cQ1	Raw response when playing col. (6-point Likert scale, 6 is maximum).
Response	Coded response quadrant.
IOT	Inter-organizational trust.
InterDep	Interdependence.
mR1	Mean centered row response.
mC1	Mean centered column response.
Deg	Angle of response vector.

+ Only fields used to calculate the response vector are shown.

The actual data has four linked pairs because each participant played eight games - four as the row actor and four as the column. For brevity only a single response is shown for three participants to illustrate the idea.

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exists a broad conceptual basis available under the rubric of linear algebra (e.g. subspaces, transformations, etc.) available to further model KEB beyond the four level construct used here.

For example, Table 4.3 below shows that participant ID 1 played hypothesis [3a] and responded with 4 'likely [to share]' when it played the row player and 5 'highly likely [to share]' when it played the column player. The mean centered coordinate pair (row,col) is (1.15,2.08) with a response angle of 61.14 ° which is in the 1st quadrant in a rectangular coordinate system and coded here as KEB promote. Thus the response is characterized both as a categorical variable [Response] and a quantitative variable [Deg].

The next row in the extract shown is for participant ID 2 who played hypothesis 2. When ID 2 played the row player the participant responded with [1] - not share and as column responded [5] most likely share. The mean centered coordinate pair is (-1.85,2.08) which is in quadrant II - KEB attenuate. The last example shown in Table 4.3 is for participant ID 3 who played hypothesis 4 and responded [5] - most likely share - when it played the row member and [1] - not share - as the column. The coordinate pair is (2.15,-1.92) which is in quadrant IV - KEB attenuate.

Table 4.3: An Example Data Extract

ID	HypoNum	rQ1	cQ1	Response	IOT	InterDep	mR1	mC1	Deg
1	3	4	5	Pr	L	H	1.15	2.08	61.14
2	2	1	5	Att	H	M	-1.85	2.08	131.66
3	4	5	1	Att	L	DA	2.15	-1.92	318.23

* The field Response is derived from the response angle (see Figure 4.4). IOT and InterDep are the values for the hypothesis being tested. The data for each participant's row and column response is paired for each value of HypoNum (scenario played) to form the dyadic response.

4.8.2 Data analysis roadmap

Since the focal phenomenon spans two levels (individual and dyadic), we start at the individual member level to assess the significance of the main effects of the predictor variables: inter-organizational trust and interdependence using a general linear model (GLM) where the individual decision to share (Q1 ' I share') is the response variable. GLM establishes the significance of the predictors and justifies the use of individual responses as components of a response vector. A GLM is performed again at the dyad level this time using the vector response angle as the dependent variable. Both the main effects and interaction effect of inter-organizational trust and interdependence are tested for significance.

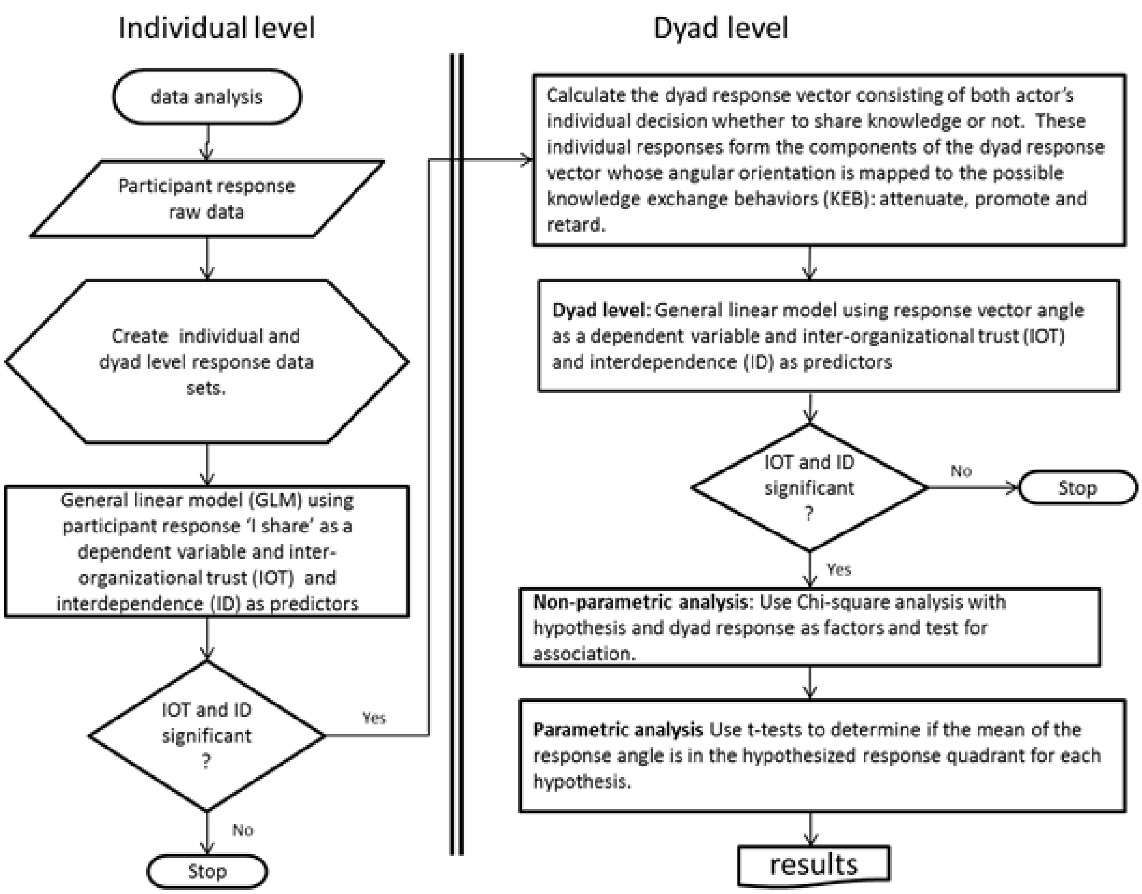

Figure 4.5: Sequence of Analysis

The interaction of IOT and interdependence is the very *basis* for the effects hypothesized. This establishes the significance of the predictor's main effects and interaction at the dyad level and justifies using response angle to test the hypothesis. Figure 4.5 illustrates the sequence of analysis prior to, and including, testing the hypotheses.

4.8.3 Testing the hypothesis

Once the validity of the predictors has been established for both levels of analysis the hypothesis are tested. The Chi-square analysis of association indicates if the environment – the conditions of IOT and interdependence - and response quadrant are correlated. The observed count vs. expected count and knowledge of the predicted response lend face validity to the parametric test because it is not as restrictive as the t- tests described next.

Next, a pair of t-tests is performed for each hypothesis. Two t-tests are needed because each of the four possible KEB responses is mapped to a quadrant bounded by a maximum and minimum angle. For example, KEB promote has a response angle between 0° and 90°. For this purpose, *both* alternate hypotheses (H_a: $\theta>0^\circ$ *and* H_a: $\theta<90^\circ$) must be significant for a stated hypothesis to be supported at a given level of significance. Figure 4.6 shows the two sets of t-tests for each response.

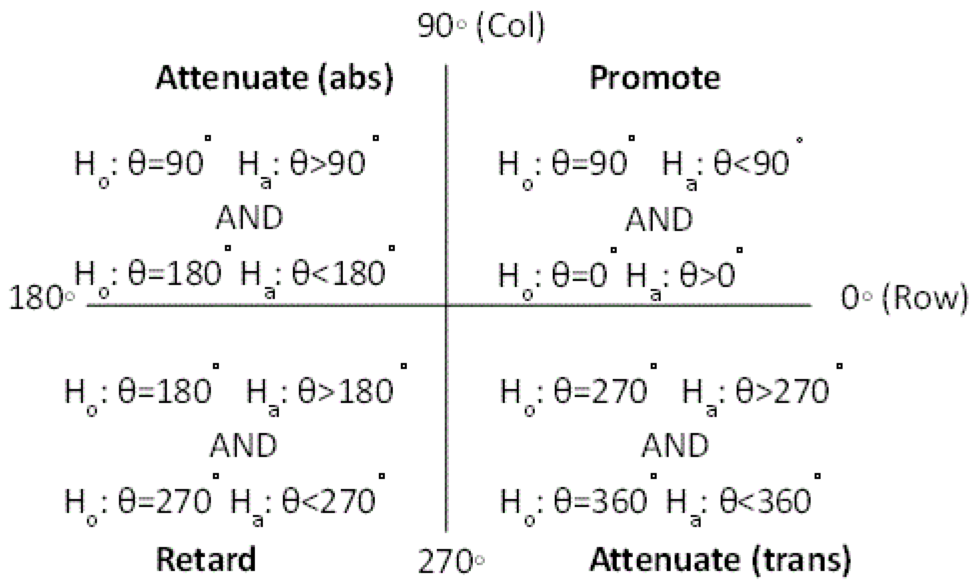

Figure 4.6: T-Test Pairs for each KEB-type

5. Results

Data was collected at the University of Cincinnati (UC) on July 29th-2014 and at the University of Houston (UH) on October 6th -2014. Both sites used business students enrolled in an operations management course – project management at UC and Supply Chain strategies at UH. The general characteristics of the participants at both sites are shown in the table below. While there does appear to be a superficial gender disparity by site this does not affect the individual response variable (p=.968).

Table 5.1: Participant Characteristics

Characteristic	UC	UH	Total
Gender			
Female	5	20	25
Male	24	11	35
(blank)		1	1
Work Experience			
Co-op/Internship	18	21	39
Experienced Individual Contributor	1		1
Individual Contributor	1	1	2
Managerial (with direct reports)	6		6
N/A		2	2
Pre-professional (i.e. seasonal work, non-career-path)	2	5	7
Self-employed Consultant		2	2
Temp. Agency	1	1	2
	n_{UC}=29	n_{UH}=32	n_{total}=61

It can be seen that a majority of the participants at both sites have had co-op/internship experience while six at UC also had managerial experience. There is no significant difference in years of work experience by site (p=.18).

Figure 5.1: Work Experience by Participant Site

The hypotheses are defined at the dyad level of analysis and the response vector is calculated using the mean-centered individual responses as the components. Since an individual participant's pairwise response – participants play the role of both members in the dyad – determines the vector angle (i.e. dyadic response), in order to treat the two sites as a single sample it is important that the variation in the individual level response (i.e. 'I share') is the same by site and by actor.

A test of homogeneity of variance shows that in fact there is no significant difference in variance of the individual responses by site or by which actor in the dyad (row or column) the participant played. Thus, any variation in the response vector angle or magnitude cannot be attributed to site location or actor (see Figure 5.2).

The equality of variance (homoscedasticity) of the individual responses between sites seems plausible when the similarity of the participant base at both sites is considered. Both sites consisted of upperclassmen operations management students most of whom had relevant industry experience. Also, the demographic composition of subjects in the two sites are not dissimilar.. Thus, for the assessment of hypotheses subjects from the two sites are pooled as a single sample (n=61).

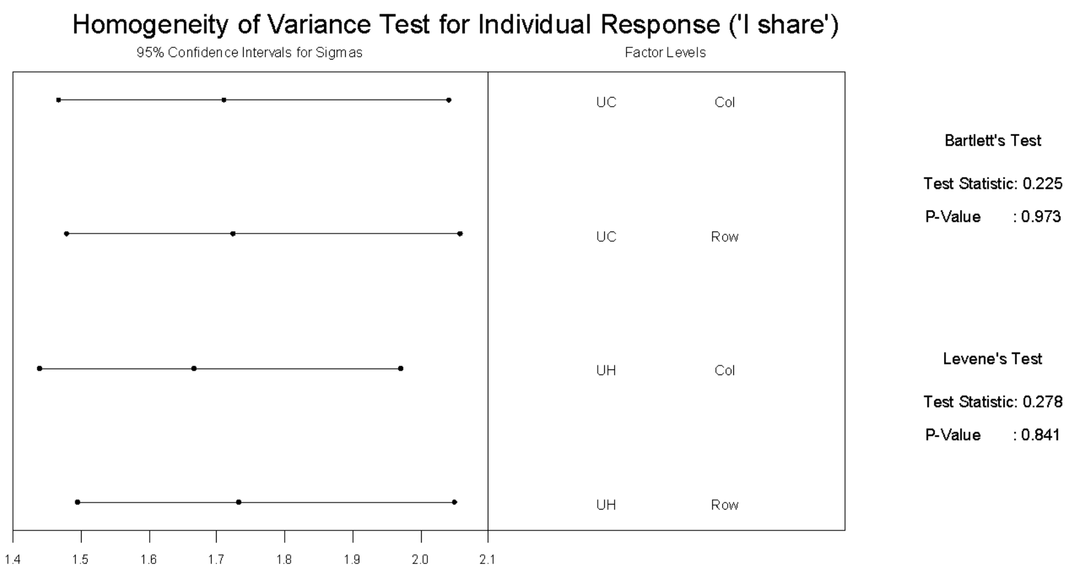

Figure 5.2: Homogeneity of Variance Test

5.1 Individual level analysis

Before embarking on hypothesis testing – a dyad level analysis – first, the significance of the effect of inter-organizational trust and interdependence are established at the individual level of analysis. This is done by using a general linear model (GLM) procedure where Q1 (‘I share’) is the dependent variable and inter-organizational trust and interdependence serve as the independent variables. Both independent variables are significant ($p<.05$).

The variables used in the data analysis are shown are listed below in Table 5.2 .

Table 5.2: Variable List and Descriptive Statistics for Data Analysis

Variable Name	Mean	SD	Min	Max	Description
Trust	3.402	1.578	1	6	Participant self-reported trust for each scenario.
Q1	2.885	1.719	1	6	A firm's KEB ('I share').
Q2	n/a	n/a	n/a	n/a	Free text field.
Q3	2.836	1.586	1	6	Partner's KEB ('I think my partner WILL share').
Q3b	2.088	2.413	1	6	'I WANT my partner to share'.
Q4	3.805	1.648	1	6	BRC – Perception of the level of independence of a firm.
Q5	2.977	1.595	1	6	MFC – A firm's perception of the level of influence exerted by its partner.
Q6	3.203	1.779	1	6	MBC- Perception of a firm about the need for task coordination.

The variable 'trust' is the participant's perception of inter-organizational trust (IOT) in the scenario encountered in each game – essentially a manipulation check.

Analysis of Variance (ANOVA) for Trust

```
Source     DF        SS        MS        F        P
IOT         1    575.61    575.61   438.71    0.000
Error     486    637.66      1.31
Total     487   1213.28
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ---------+---------+---------+-------
H         244     4.488     1.195                              (-*-)
L         244     2.316     1.094  (-*-)
                                   ---------+---------+---------+-------
Pooled StDev =    1.145                   2.80      3.50      4.20
      r-sq =.47
```

The results of the ANOVA above indicates that self-reported trust is significantly different (p = .000) for the two levels (high/low) of IOT. Indeed, 47% of the variation in self-reported trust is explainable by IOT suggesting that inter-organizational trust was successfully induced. Self-reported trust correlates significantly with all of the perceptual measures used in the post-scenario survey (see Table 5.2) . This suggests that the perception of trust of partner intentions is influenced by the behavior components or vice versa (e.g. if the partner firm will share [Q3] or the need to coordinate with that partner [Q6]).

Correlation: Trust, Q1, Q3, Q4, Q5, Q6

	Trust	Q1	Q3	Q4	Q5
Q1	0.489				
	0.000				
Q3	0.523	0.565			
	0.000	0.000			
Q4	0.251	-0.255	-0.260		
	0.000	0.000	0.000		
Q5	0.199	0.255	0.306	-0.503	
	0.000	0.000	0.000	0.000	
Q6	0.534	0.673	0.625	-0.340	0.306
	0.000	0.000	0.000	0.000	0.000

Cell Contents: Pearson correlation

A general linear model (GLM) is used to assess the significance of IOT and interdependence. The GLM is first run (below) with all the response variables included to identify which are not significant and which need to be used as covariates.

General Linear Model

Factor	Type	Levels	Values
Player*	fixed	2	Col Row
Q3	fixed	7	0 1 2 3 4 5 6
Q4	fixed	7	0 1 2 3 4 5 6
Q5	fixed	7	0 1 2 3 4 5 6
Q6	fixed	7	0 1 2 3 4 5 6
IOT	fixed	2	H L
InterDep	fixed	4	DA H L M
SiteIndi	fixed	2	0 1

*Player is which role the participant is playing (row or column).

Analysis of Variance for KEB (Q1), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Player	1	0.525	0.254	0.254	0.18	0.675
Q3	6	466.281	22.699	3.783	2.63	0.016
Q4	6	32.874	5.922	0.987	0.69	0.660
Q5	6	6.739	7.029	1.172	0.82	0.558

Q6	6	241.355	156.191	26.032	18.12	0.000
IOT	1	6.127	19.102	19.102	13.30	0.000
InterDep	3	27.998	28.734	9.578	6.67	0.000
SiteIndi	1	1.112	1.112	1.112	0.77	0.379
Error	457	656.563	656.563	1.437		
Total	487	1439.574				

r-sq=.54

The site (UH or UC) was not significant (p=.38) further justifying the use of a combined sample. The non-significant variables are now removed and the GLM run using Q3 and Q6 as covariates. IOT and interdependence are significant (below) and 52% of the variation in the response variable Q1 is explainable with this model.

General Linear Model

Factor	Type	Levels	Values
IOT	fixed	2	H L
InterDep	fixed	4	DA H L M

Analysis of Variance for Q1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Q3	1	460.23	24.22	24.22	16.81	0.000
Q6	1	241.18	139.70	139.70	96.97	0.000
IOT	1	7.43	22.10	22.10	15.34	0.000
InterDep	3	37.77	37.77	12.59	8.74	0.000
Error	481	692.96	692.96	1.44		
Total	487	1439.57				

r-sq=.52

5.2 Dyad Level Analysis

Next, the dyad response vectors are calculated as previously described in Section 4.8.1. Earlier, the significance of the predictor variables (IOT and interdependence) was assessed at the individual level of analysis. At the dyad level, only IOT and interdependence can be considered since Q1-Q6 are individual level variables. The dependent variable, KEB of the dyad, in the GLM is the response vector angle. Since the hypotheses pertain to the interaction between IOT and Interdependence, it is critical that the interaction (IOT * Interdep) be significant. In fact, in a pure technical sense, it is inappropriate to proceed with additional drill-down analyses unless the interaction effect is significant.

General Linear Model

```
Factor      Type Levels Values
IO_T       fixed      2 H L
Interdep   fixed      4 DA H  L  M

Analysis of Variance for KEB, using Adjusted SS for Tests
Source           DF     Seq SS     Adj SS     Adj MS       F      P
IOT               1     220934     280531     280531   39.86  0.000
Interdep          3     416230     373731     124577   17.70  0.000
IOT*Interdep      3     126438     126438      42146    5.99  0.001
Error           236    1661076    1661076       7038
Total           243    2424678
      r-sq=.31
```

The results of the GLM procedure above indicates that the interaction (IOT * Interdep) is significant (p <= .001) even after partialling out the main effects of the two variables. The interaction plot below shows how the mean response angle is influenced by changing the level of the predictor variables.

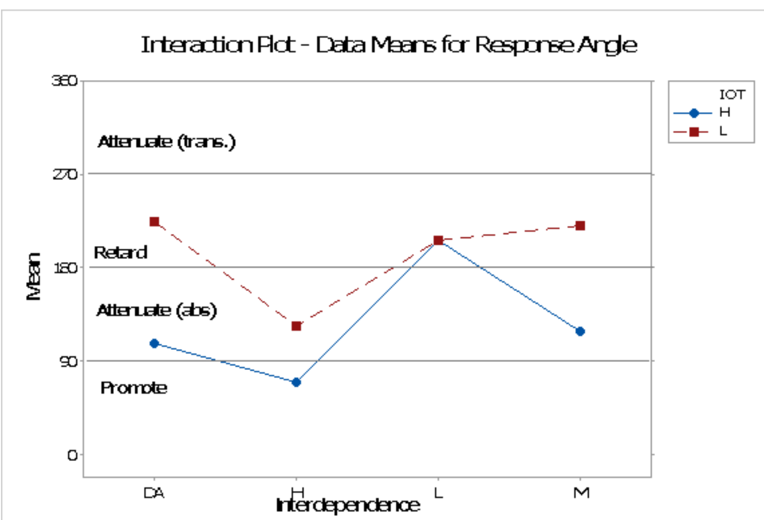

Figure 5.3: Interaction Plot of KEB vs. ID and IOT

The non-parallel line segments for high and low IOT graphically confirms the interaction effect (Figure 5.3). Observe that the response angle changes across IOT levels depending on the level of interdependence. When interdependence is low there is very little effect on the response angle when IOT is changed from high to low. The effect of IOT is more pronounced - as seen by the separation of the mean response angle on the plot - when interdependence is high, moderate or DA.

Hypothesis testing proceeds as follows:

- first KEB as a categorical response - i.e. which quadrant: Promote, Retard, Attenuate (absorptive) and Attenuate (transmissive) - is analyzed using a Chi-square test for association;
- then KEB as interval data (the response angle) is analyzed using a series of t-tests.

Such triangulation in hypothesis testing is expected to enhance the robustness of the results.

The response coordinate system and space of interdependence (Figure 5.4) is included again to aid in interpreting the chi-square and t-test results presented next. The specific effect expressed in each hypothesis is enabled by unique combinations of the levels of the independent variables, IOT and ID (composed of JD and DA). For instance, H1a captures the effect on KEB caused by low IOT and low ID (low JD and no DA). For ease of reference in data analysis, the effects induced by the hypotheses H1a, H1b, H2a, H2b, etc. are henceforth labeled as H1a, H1b, H2a, H2b, etc. respectively.

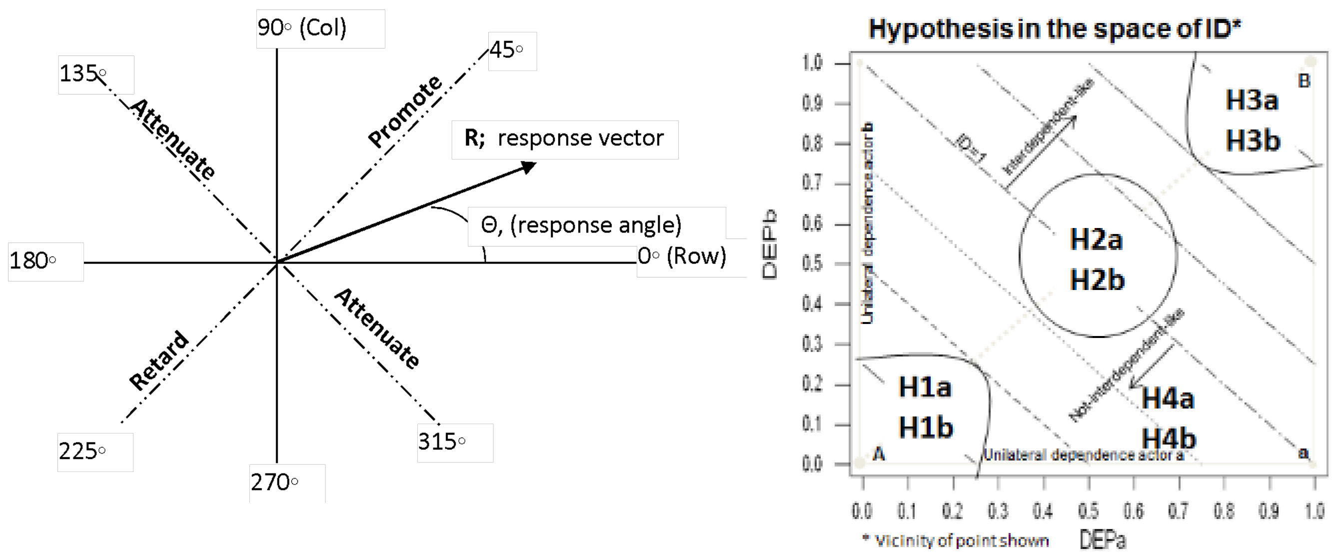

Figure 5.4: Response Vector Coordinate System and Space of ID

Shown below are the results for the Chi-Square test for association. The dashed circles indicate unsupported hypotheses. Two hypotheses are not supported: H4b (high trust, high DA) and H2b (high trust, moderate ID).

```
Rows: HypoNum    Columns: Response
          Att1    Att2        Pr        Re   All

1b           9       8         4        14    35
         4.447   5.307    12.193    13.053
         4.662   1.366     5.505     0.069

4b           2       7        15         2    26
         3.303   3.943     9.057     9.697
         0.514   2.371     3.899     6.109

3b           2       1        23         0    26
         3.303   3.943     9.057     9.697
         0.514   2.196    21.463     9.697

2b           4       4        21         6    35
         4.447   5.307    12.193    13.053
         0.045   0.322     6.362     3.811

1a           0       2         2        22    26
         3.303   3.943     9.057     9.697
         3.303   0.957     5.499    15.610

4a           7       4         2        22    35
         4.447   5.307    12.193    13.053
         1.466   0.322     8.521     6.132

3a           5       9        17         4    35
         4.447   5.307    12.193    13.053
```

```
       0.069  2.569   1.895   6.279

2a         2      2       1      21   26
       3.303  3.943   9.057   9.697
       0.514  0.957   7.168  13.176

All       31     37      85      91  244
Cell Contents:      Count
                    Expected count
                    Contribution to Chi-square
Pearson Chi-Square = 143.344, DF = 21, P-Value = 0.000
Likelihood Ratio Chi-Square = 158.628, DF = 21, P-Value = 0.000
* NOTE * 12 cells with expected counts less than 5
```

The dyad response variable used in the Chi-square test is a categorical variable with four levels (Promote, Retard, Attenuate absorptive, Attenuate transmissive) – the quadrants of the rectangular coordinate system. A t-test is used in somewhat a similar manner:

- The t-test is performed twice to verify if the mean response angle falls within the boundary values of the appropriate sector.

For example, KEB promote is tested as follows:

- H_o: $\theta=0^{\circ}$ H_a: $\theta>0^{\circ}$ ***and*** H_o: $\theta=90^{\circ}$ H_a: $\theta<90^{\circ}$.
- Only if Ho is rejected for *both* tests, can the response angle belong in that quadrant – here quadrant I (promote KEB).

A similar basis applies for the other three KEB responses (see Figure 5.4).

Hypotheses H1a, H1b, H2a and H4a have a predicted KEB response of 'retard' which is in quadrant III (between 180° and 270°); thus the tests are H_o: $\theta=180^{\circ}$ H_a: $\theta>180^{\circ}$ and H_o: $\theta=270^{\circ}$ H_a: $\theta<270^{\circ}$. The results are shown next.

```
Test of mu = 180.0 vs mu > 180.0

Variable      N      Mean    StDev   SE Mean         T          P
H1a          22     225.2     12.9       2.8     16.37     0.0000
H1b          35     206.6     89.8      15.2      1.75     0.044
```

H2a	22	223.3	15.3	3.3	13.22	0.0000
H4a	26	226.3	22.4	4.4	10.53	0.0000

Test of mu = 270.0 vs mu < 270.0

Variable	N	Mean	StDev	SE Mean	T	P
H1a	22	225.2	12.9	2.8	-16.24	0.0000
H1b	35	206.6	89.8	15.2	-4.17	0.0001
H2a	22	223.3	15.3	3.3	-14.29	0.0000
H4a	26	226.3	22.4	4.4	-9.95	0.0000

The response vector angle for all of H1a, H1b, H2a, and H4a have means greater than 180° and less than 270° and are significant at α=.05 thus supporting these hypotheses. Observe that the Chi-square analysis and the t-tests for these four hypotheses are mutually ratifying.

H4b is hypothesized to be KEB attenuate (where row withholds knowledge while its partner does share knowledge). This is in quadrant II and the tests are H_o: $\theta=90^\circ$ H_a: $\theta>90^\circ$ and H_o: $\theta=180^\circ$ H_a: $\theta<180^\circ$.

Test of mu = 90.0 vs mu > 90.0

Variable	N	Mean	StDev	SE Mean	T	P
H4b	24	90.2	64.1	13.1	0.02	0.49

Test of mu = 180.0 vs mu < 180.0

Variable	N	Mean	StDev	SE Mean	T	P
H4b	24	90.2	64.1	13.1	-6.86	0.0000

H4b is not fully supported because we cannot say the response is greater than 90° (p=.49) but we are confident it is less than 180°. The 95% confidence interval is [63.2,117.3]; thus, the response straddles quadrants I and II (KEB promote and attenuate). This agrees with the Chi-square analysis which shows the highest observed frequency occurs in the KEB promote and

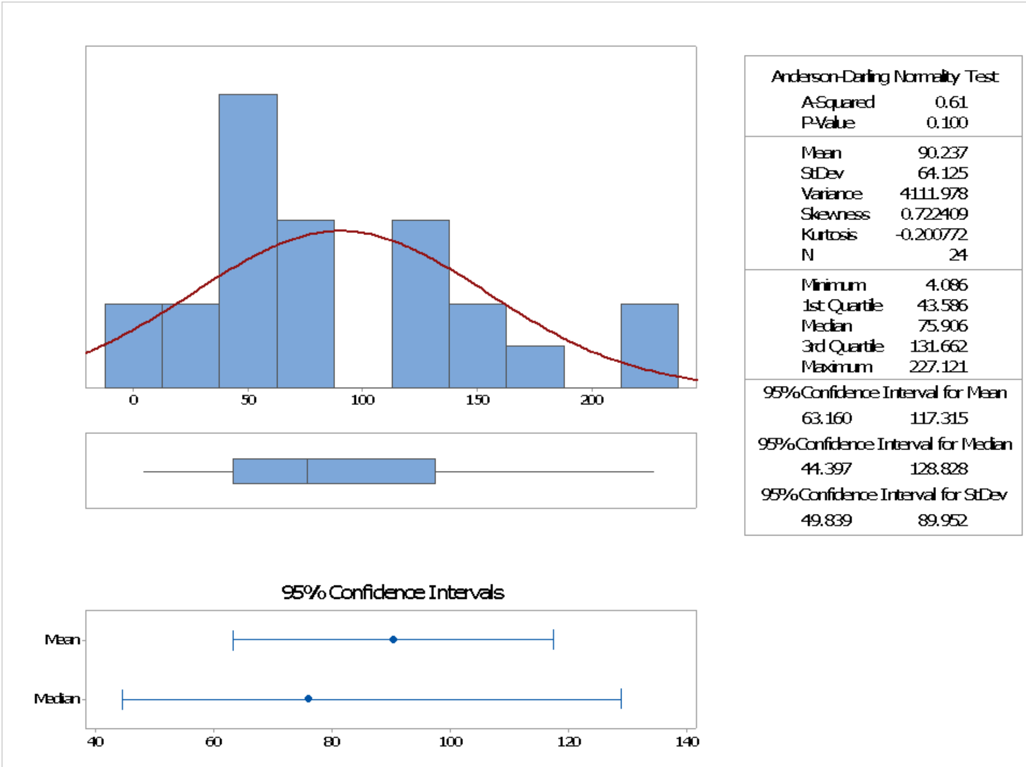

Figure 5.5: Descriptive Statistics for H4b

KEB attenuate categories. The histogram in Figure 5.5 suggests that the responses for H4b are perhaps coming from two populations since there appears to be a median split – two distinct groups separated by the median (note empty bin between the groups); a t-tests shows that the above and below median groups have significantly different means (p <=.001)

Hypotheses H3a and H3b propose a KEB response of ‘promote’; therefore the tests are: H_o: $\theta=0^\circ$ and H_a: $\theta>0^\circ$ and H_o: $\theta=90^\circ$ H_a: $\theta<90^\circ$.

Test of mu = 0.00 vs mu > 0.00

Variable	N	Mean	StDev	SE Mean	T	P
H3a	35	124.49	108.01	18.26	6.82	0.0000
H3b	23	41.54	14.30	2.98	13.93	0.0000

Test of mu = 90.00 vs mu < 90.00

Variable	N	Mean	StDev	SE Mean	T	P
H3a	35	124.49	108.01	18.26	1.89	0.97
H3b	23	41.54	14.30	2.98	-16.25	0.0000

H3b is supported while H3a is not supported. Similar to the case for H4b, the response for H3a appears to straddle two responses (promote and attenuate) as shown in Figure 5.6 below. The 95% confidence interval for the response is [87.4,161.6] which straddles quadrant I and II. This is also reflected in the results for the Chi-square analysis where the two highest observed responses were in the KEB promote and KEB attenuate categories.

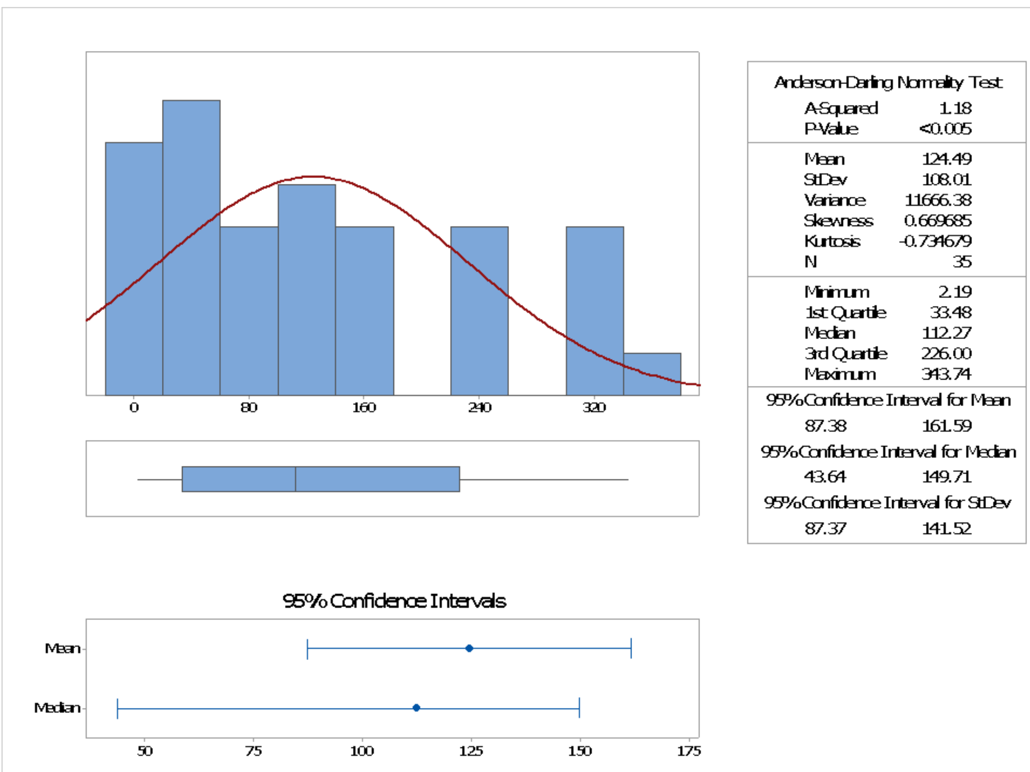

Figure 5.6: Descriptive Statistics for H3a

H2b was hypothesized as KEB attenuate (row supplies knowledge while column withholds). This is in quadrant III and the tests are: H_o: $\theta=270^{\circ}$ H_a: $\theta>270^{\circ}$ and H_o: $\theta=360^{\circ}$ H_a: $\theta<360^{\circ}$.

```
Test of mu = 270.0 vs mu > 270.0

Variable      N      Mean    StDev    SE Mean         T          P
H2b          35     118.9    103.6       17.5     -8.63       1.00
```

```
Test of mu = 360.0 vs mu < 360.0
Variable      N      Mean     StDev    SE Mean        T          P
H2b          35     118.9     103.6       17.5   -13.77     0.0000
```

H2b is not supported. The 95% confidence interval for its response is [83.3,154.5] which straddles KEB promote and KEB attenuate.

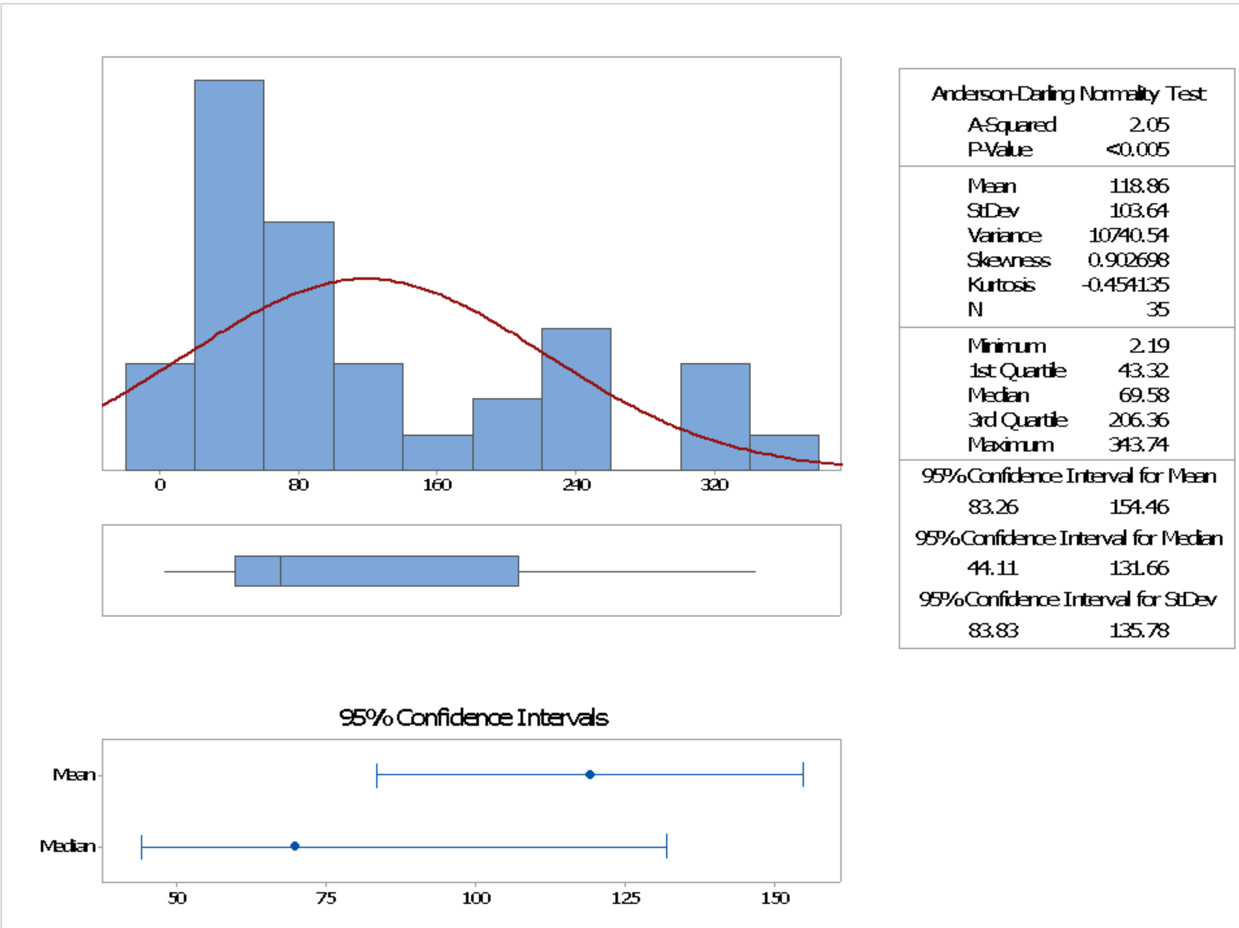

Figure 5.7: Descriptive Statistics for H2b

5.3 Summary of Results

A summary of the data analysis results appear in Table 5.3.

Table 5.3: Summary of Results

n*	Hypo	IO Trust	Interdependence	Predicted	Method: Chi-Sq	Method: T-test	Support
22	1a	Low	Low	Retard	Yes	Yes	Yes
22	2a	Low	Mid	Retard	Yes	Yes	Yes
35	3a	Low	High	Promote	Yes	No	Marginal
26	4a	Low	Asymmetric	Retard	Yes	Yes	Yes
35	1b	High	Low	Retard	Yes	Yes	Yes
35	2b	High	Mid	Attenuate	No	No	No
23	3b	High	High	Promote	Yes	Yes	Yes
24	4b	High	Asymmetric	Attenuate	No	No	No

* data points greater than 1.5 x interquartile range (Q_3 - Q_2) above the third quartile (Q_3) or below the first quartile (Q_1) were trimmed as outliers. This included 3 data points for H2b, none for H3a and 1 for H4b. Support α=.05

6. Discussion of Findings

This dissertation documents findings from a research project which extends a previous investigation that "…focuse[d] on the crucial yet long overlooked question of why partners sometimes hesitate to share knowledge despite the apparent benefits from knowledge sharing." (Kim et al, 2012). In that work, Kim, et. al. encountered a surprising result. Contrary to their hypothesized expectation, they found that knowledge exchange *decreased* as inter-organizational trust increased. This finding, and the generally conflicting role of trust in the literature regarding knowledge exchange, served as the principal motivation for this dissertation research.

The unexpected finding in the originating study of Kim, et. al. (2012) is tested in this research with hypothesis H1b (high inter-organizational trust will result in KEB being retarded when knowledge interdependence in the supply channel dyad is low) and is ratified. We believe that this study validates the speculation in Kim et al (2012) that trust alone is an insufficient antecedent to KEB and instead other contingencies act concomitantly with trust to influence knowledge sharing behavior. This research investigates the role of trust on knowledge exchange behavior under different conditions of interdependence and the consequent incentive structures finding strong support overall for the contingency model developed in this work.

There are, however, three hypotheses (out of eight) that are not supported. They are:

H2b: *In a supply channel engagement with moderate interdependence, knowledge exchange behavior among supply channel partners is attenuated even when inter-organizational trust is high.*

Finding: Not supported. The observed response straddles two responses (promote and attenuate).

H3a: *In a supply channel engagement with high interdependence, knowledge exchange behavior among supply channel partners is promoted even when inter-organizational trust is low.*

Finding: Marginal support. Chi-square test for association is suggestive; however, this is not validated by the t-tests.

H4b: *In a supply channel engagement with high dependence asymmetry, knowledge exchange behavior among supply channel partners is attenuated even when inter-organizational trust is high.*

Finding: Not supported. The observed response straddles two responses (promote and attenuate).

The rest of this section will attempt to unearth possible reasons for the lack of support for these three hypotheses and will conclude with a vision of future research.

6.1 Ex post analysis

Figure 6.1 represents the predicted KEB response for each of the three unsupported hypotheses compared to the actual response. The bold frames are the predicted response quadrants; the 95% confidence interval of the actual response angle is shown by arcs subtending the range of angles. The actual responses for all three unsupported hypotheses straddle quadrants I and II – KEB promote and KEB attenuate. As can be seen in the left panel in Figure 6.1, the difference between the predicted and actual response is greatest for H2b. The other two hypotheses – H3a and H4b – show actual responses which can occasionally fall in the predicted quadrant.

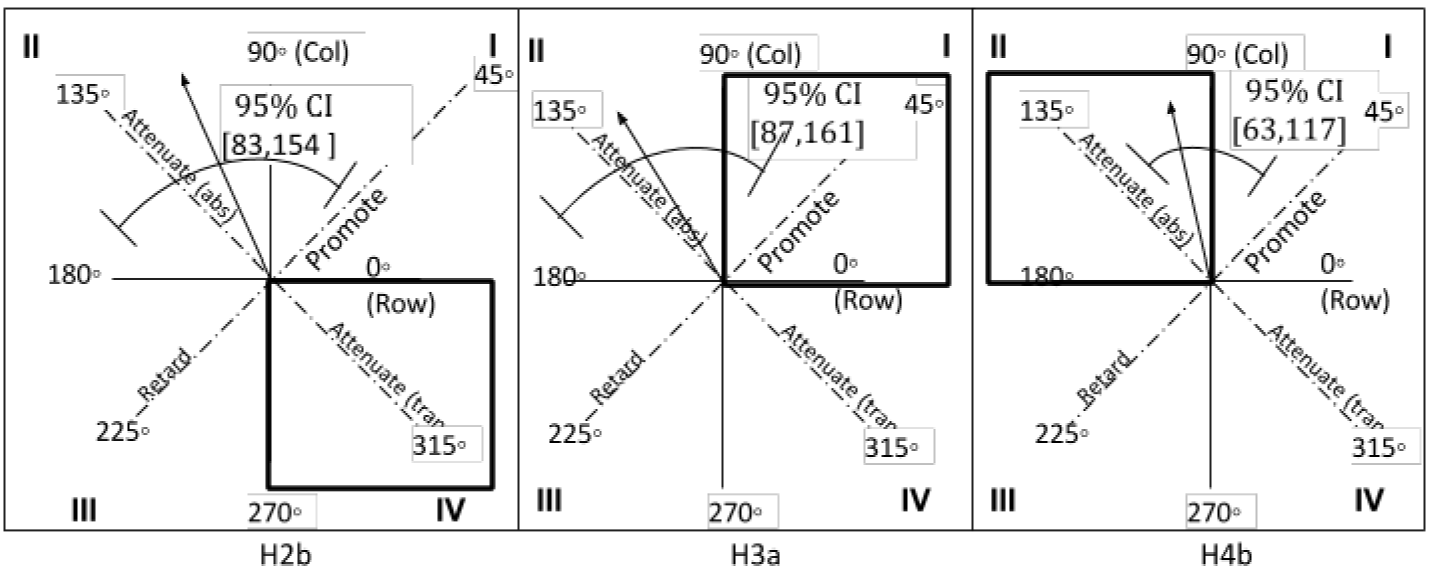

Figure 6.1: Unsupported Hypothesis - Predicted vs. Actual Response

The lack of empirical support for H2b, H3a and H4b can either be

- a theoretical issue: deficient theoretical basis (perhaps, a missing contingency) or
- an operationalization issue: perhaps, a failure in sufficient inducement of the effect of one or more independent variables.

The latter possibility can be empirically evaluated. Simply, if the levels of theoretical variables, IOT and interdependence, were not sufficiently induced, then the theory was not tested for that condition. It is perhaps apt to remind the reader at this point that knowledge interdependence

(ID) is composed of joint dependence (JD) and dependence asymmetry (DA). In hypotheses H1 through H3, DA is held constant (in fact, at or near zero) and in H4, JD is held constant - please see Figure 5.4 in Section 5. In other words, interdependence hypothesized are either JD-dominant (H1, H2, H3) or DA-dominant (H4).

Inter-organizational trust and interdependence are induced through the elements of the scenario presented in the simulation and the participants perception is captured by a survey after each scenario. The relevant survey items are reproduced below:

- **Q0**: Based on the information provided, how likely are you to trust your partner?
- **Q4**: In this engagement, given the payoff structure for both firms, are you able to ACT INDEPENDENTLY AT ALL without paying heed to your partner firm's action?
- **Q5**: In this engagement, given the payoff structure for both firms, does your partner firm have ANY CONTROL AT ALL on your actions?
- **Q6**: In this engagement, given the payoff structure for both firms, are you and your partner firm likely to cooperate?

It is possible that for the unsupported hypotheses the desired level of the theoretical variables were not induced. If this was in fact the case, the hypothesized effect may resemble a different condition to the participant. One useful technique to determine this is hierarchal cluster analysis. In *hierarchal cluster analysis* each variable (here a hypothesis) is treated as a vector and its similarity (i.e. proximity) to other hypotheses are calculated.[11] The results are represented

[11] Each hypothesis is represented as a vector whose elements are the participant responses. These vectors form a space (the set of all hypothesis). The *similarity* measure for the hypotheses is computed as the Euclidean distance between vector pairs.

in a dendrogram (i.e. an inverted tree diagram) where the shorter a branch is, the closer the objects in that cluster are (i.e. are more similar to each other). Clusters may be nested until at a far enough distance all objects are in a single cluster; hence the hierarchical nature.

The dendrogram shown in Figure 6.2 shows how the hypotheses cluster based on similarity using the participant responses to the end-of-scenario survey elements (Q4, Q5 and Q6). It can be seen that there are three tight clusters: H4b-H3b, H1b-H2b and H1a-H2a-H4a. While H3a stands relatively apart in the dendrogram, it can be used as a contrast in the first cluster (H4b-H3b) for testing the inducement of IOT and ID – the conditions represented by H3a are very different from the rest based on the participant's perception. Henceforth, H3a will be ***adjoined*** to cluster H4b-H3b for purposes of further analysis and designated as H4b-3b|H3a. While H3a is somewhat remote from H4b-H3b, it still clusters with H4b-H3b at a higher level of hierarchy. The reason for the choice of H3a is that it enables a clearer contrast for the cluster H4b-H3b in the analysis.

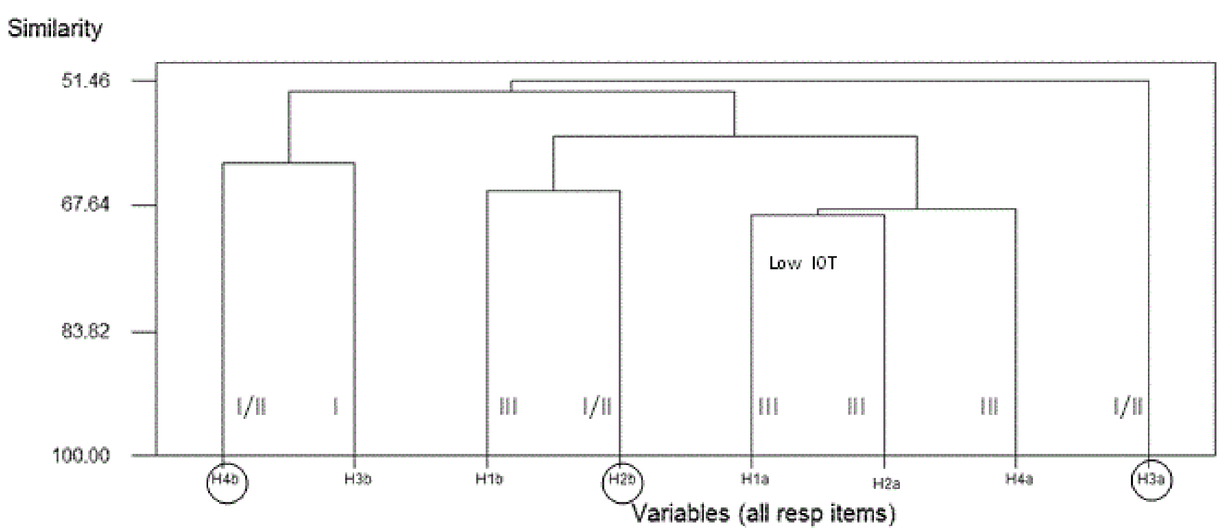

Figure 6.2: Dendrogram of Unsupported Hypothesis

The circles in Figure 6.2 indicate unsupported hypotheses while the Roman numeral figures indicate the actual response quadrant (e.g. ‘I’ is KEB promote) in a rectangular coordinate system. It can be seen that H4b pairs with H3b, a ratified hypothesis and H2b pairs with another supported hypothesis, H1b suggesting similarity; note that KEB responses are not the same. It should also be noted that while the members in a cluster share similarities they are also distinct. This can have implications for the possible reasons why some of the conditions lack empirical support.

The two clusters H4b-H3b|H3a and H1b-H2b each contain a ratified and unsupported condition. The unsupported hypothesis – for example H4b in the first cluster – share similarities to a condition (H3b) which found support. How similar two or more members are, is based on the participant’s perception of inter-organizational trust and interdependence. H4b (high IOT, DA-dominant ID) shares similarities to H3b (high IOT, high JD-dominant ID). Thus, either IOT and/or ID was not induced in H4b or there is a conceptual issue related to H4b to render the hypothesis unsupported.

For each cluster containing an unsupported condition (H4b-H3b|3a and H1b-H2b) the actual level of induced IOT and ID is determined. The perceived IOT level can be determined by using an ANOVA with pairwise comparisons for the self-reported trust using:

- The unsupported hypothesis.
- The supported hypothesis in the cluster and
- The counterpart for the supported hypothesis in the cluster.

Since the intended IOT is known for all the tested hypotheses, this analysis will help determine if IOT was induced at the intended level (high or low).

Next, after the induced IOT state of each of the hypotheses in the cluster have been determined, the effect of perceived interdependence is evaluated by considering the behavioral components (BRC,MFC and MBC) as captured by the end of scenario survey items Q4,Q5 and Q6 respectively. Observe that this is the best approximation possible to assess the induced level of interdependence; concordance/discordance among BRC, MFC and MBC as well as correspondence within the MBC component also impact interdependence and are not accounted for in the isolated evaluations of the three components.

The magnitude of a component mean for a hypothesis relative to all of the other hypotheses provides an indication of how strong that component is for the hypothesis in question. For example, H1a represents a low interdependence condition in contrast to H3a which represents high interdependence. Consequently, the mean response for Q4 (BRC) ought to be higher (lower dependence) for H1a than for H3a. In fact, the mean responses for H1a and H3a are:

Hypo	N	Mean	StDev	95% CI
H1a	52	4.962	1.571	(4.547, 5.376)
H3a	70	3.229	1.395	(2.871, 3.586)

H1a has a higher mean response for Q4 than H3a meaning that under the conditions modelled by H1a, the actor feels more independent than that modelled by H3a as shown in the pairwise comparison.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value

```
H3a - H1a        -1.733       0.279  (-2.578, -0.888)    -6.22     0.000
```

Figure 6.3 shows the 95% CI for each component by hypothesis. Confidence intervals that do not overlap imply that the means are different for an α = 0.05. Pairwise comparisons will confirm this numerically; nonetheless, Figure 6.3 is a useful visualization.

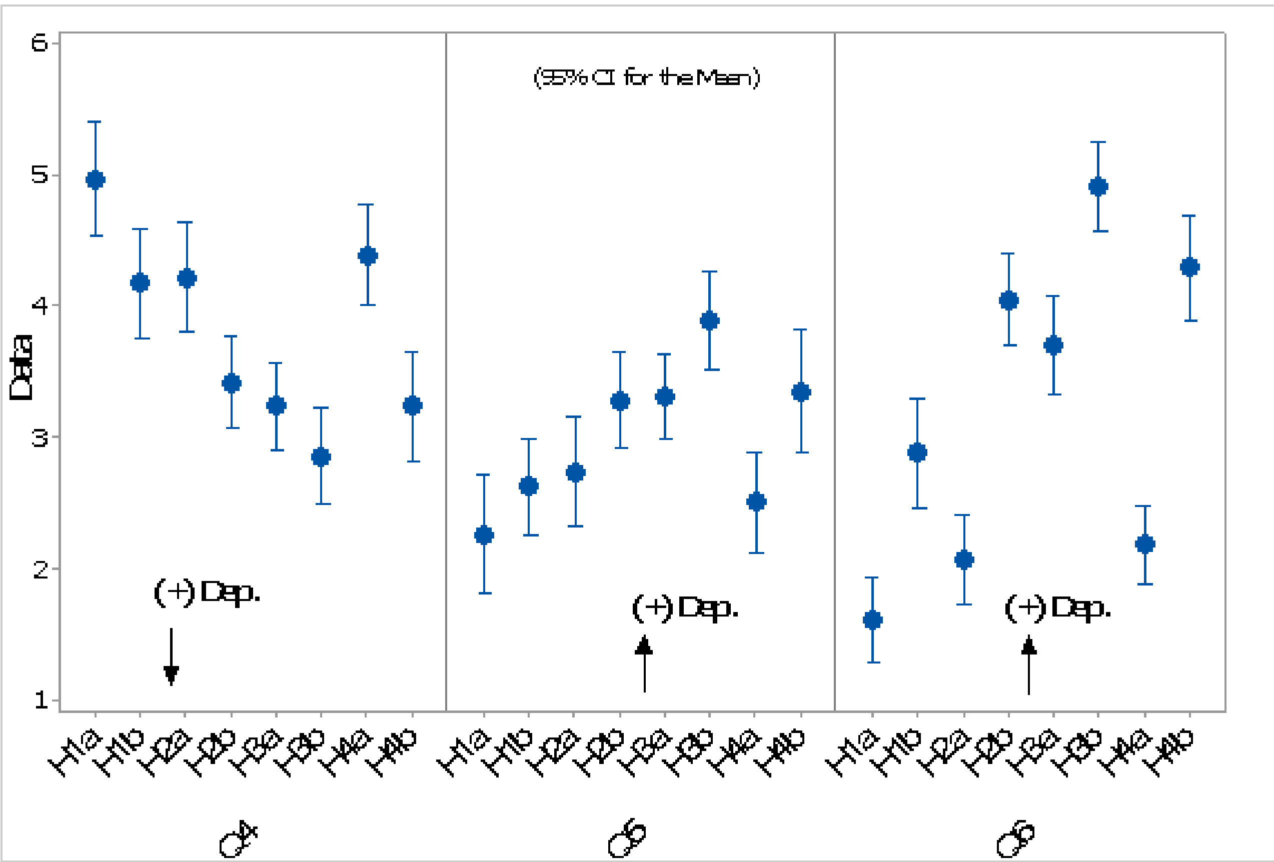

Figure 6.3: Trust and Behavior Component Means by Hypothesis

The next sections will discuss each of the three distinct clusters:H4b-H3b|H3a, H1b-H2b and H1a-H2a-H4a in an effort to illuminate potential reasons for the lack of support for H2b, H3a and H4b. The hypotheses in the last cluster – H1a-H2a-H4a - are all supported; in addition, all three have the same KEB response (retard) and thus are perceived as similar. In essence, for a low IOT condition, interdependence is indistinguishable across low, moderate and asymmetric dependence levels - an intriguing inference.

6.1.1 Cluster H4b-H3b|H3a

H4b (high IOT, high dependence asymmetry) is not supported, yet clusters with (i.e., is perceived similar to) H3b (high IOT, high ID) which is ratified. It is expected that H3b and H4b have a higher perceived trust state than H3a and they do as seen in the ANOVA and pairwise comparison shown below.

One-way Analysis of Variance

```
Analysis of Variance for Trust
Source     DF        SS        MS        F        P
NewHypo     2    109.10     54.55    41.97    0.000
Error     171    222.25      1.30
Total     173    331.36
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  ----+---------+---------+---------+--
H3a        70     2.843     1.137   (---*--)
H3b        52     4.365     1.221                      (---*----)
H4b        52     4.538     1.056                        (----*---)
                                   ----+---------+---------+---------+--
Pooled StDev =    1.140              2.80      3.50      4.20      4.90

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Clus3a3b4b   N   Mean  Grouping
H4b         52  4.538  A
H3b         52  4.365  A
H3a         70  2.843    B

Means that do not share a letter are significantly different.


Tukey Simultaneous Tests for Differences of Means

Difference  Difference       SE of                            Adjusted
of Levels     of Means  Difference        95% CI      T-Value   P-Value
H3b - H3a        1.523       0.209  ( 1.030, 2.015)      7.29     0.000
H4b - H3a        1.696       0.209  ( 1.203, 2.189)      8.12     0.000
H4b - H3b        0.173       0.224  (-0.355, 0.701)      0.77     0.719
```

Indeed, there is no statistically significant difference in trust perception between H4b and its supported neighbor H3b. H3b is for high IOT and therefore H4b is also being perceived as high IOT (see the pairwise comparison). IOT for H3a is being perceived as significantly lower than H3b (p = .000) suggesting that H3a is being perceived as low IOT as intended. Thus, we can conclude that H3a and H4b did have the proper inducement of IOT and the the lack of empirical support for H4b and H3a cannot be due to IOT. The explanation then must lie with either the inducement of interdependence or a deeper conceptual issue associated with these two conditions or a missing contingency in the research model.

With the proper inducement of IOT having been established for all members in the H4b-H3b|H3a cluster, next the effect of interdependence is evaluated. As a high interdependence condition, H3a would be expected to have a weaker mean response for Q4 (BRC) compared to the other extreme - low interdependence - making H1a a useful contrast in evaluating the inducement of interdependence in H3a. As seen in Figure 6.3 this does appear to be the case and is substantiated by the pairwise comparison shown below.

Tukey Simultaneous Tests for Differences of Means: Q4 (BRC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H3a - H1a	-1.733	0.279	(-2.578, -0.888)	-6.22	0.000

Further using H1a as the antipode to H3a it would be expected that the mean response for Q5 (MFC) and Q6 (MBC) would be less for H1a. As the pairwise comparison of the means (and Figure 6.3) show, this is in fact the case.

Tukey Simultaneous Tests for Differences of Means: Q5 (MFC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H3a - H1a	1.050	0.280	(0.202, 1.898)	3.76	0.004

Tukey Simultaneous Tests for Differences of Means: Q6 (MBC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H3a - H1a	2.104	0.261	(1.311, 2.897)	8.05	0.000

A closer examination of H3a reveals, however, that its MBC component is different from its counterpart H3b in spite of both representing the same interdependence condition.

Tukey Simultaneous Tests for Differences of Means: Q6 (MBC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H3b - H3a	1.204	0.261	(0.411, 1.997)	4.61	0.000

The means for the other two components - BRC and MFC - are not significantly different between H3a and H3b ($p>.05$).

Given that BRC and MFC responses indicate similar interdependence conditions between H3a and H3b, one can speculate that perhaps the difference in the coordination requirement (MBC) is due to the difference in trust conditions between H3a (low IOT) and H3b (high IOT) thus alluding to a possible relationship between Trust and MBC. So, perhaps the failure to ratify H3a ought to be pursued as more of a theoretical issue than the easy way out of a failure to operationally induce the correct level of interdependence. A close review of the conceptual development of this dissertation research triggered by the empirical finding here about MBC provides a lead towards a possible theoretical gap. The conceptual framework of this research does not account for the 'reciprocity norm' which is well known in the trust and social exchange theory literature (e.g. Blau, 1964).

In that case, this inadequacy should somehow manifest itself in the game matrix. An examination of the game matrix follows. It was noted during hypothesis development (Section

3.7.1) that the game used for H3a and H3b does not have a Nash equilibrium. A closer inspection of the resultant matrix (Figure 3.23) reveals that it is equivalent to what Rapoport (1967) classifies as a cycle game. A *cycle game* results when neither actor has a dominant strategy; there is no Nash equilibrium nor is there a Pareto optimal solution. Specifically, in Rapoport's taxonomy of 2x2 games, this type is captured in game 76, a class III game (a set of game where neither actor has a dominant strategy). A cycle game has no stable equilibrium meaning that in pure self-interested behavior (i.e., game-theoretic strategy) - as in a low trust state - the response would cycle through different KEB responses. A partial cycle is in fact observable for H3a because the observed responses straddle quadrants I (KEB promote) and II (KEB attenuate). The cycle, however, is not complete because quadrant III (KEB retard) or IV (KEB attenuate) responses for this hypothesis are very few (insignificant). The game-theoretic strategy would lead the initial KEB response of both actors to 'KEB promote' simply because in a low trust state both actors know that its partner would 'retaliate' if one attempted a self-maximizing solution. However, this 'deterrence' need not be stable. Indeed, even games with a much clearer incentive to cooperate like the Prisoner's dilemma (PD) game show that cooperation tends to break down (e.g. Deutsch, 1959). However, under a low trust condition in a dyad any apparent cooperation cannot be attributed to cooperative intent. Axelrod (1981) demonstrated that especially under a low trust state a 'tit-for-tat' strategy yields the best outcome for both actors. Essentially, each actor simply mimics what it observes its partner to do. Since the perceived coordination requirement is lower for H3a (see below) it appears that the lack of support for H3a can be attributed to a conceptual deficiency in this research perhaps because it does not account for the 'reciprocity norm' - a seed for future extension of this research.

Tukey Simultaneous Tests for Differences of Means: Q6 (MBC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H3b - H3a	1.204	0.254	(0.474, 1.934)	4.73	0.000

Turning our attention next to H4b (high IOT, high dependence asymmetry), the first operational question is whether the actor perceived dependence differently when playing row vs column. Referencing Figure 6.3 and the pairwise comparisons below, it is clear that Q4 was not perceived differently for row or column for either H4a or H4b.

Tukey Simultaneous Tests for Differences of Means: Q4 (BRC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4a_Row - H4a_Col	0.086	0.349	(-0.915, 1.086)	0.25	1.000
H4b_Row - H4b_Col	0.615	0.404	(-0.545, 1.776)	1.52	0.651

In fact for both H4a and H4b none of the components - BRC, MFC and MBC - were perceived differently between the row or column actor (p>.05) - see pairwise comparisons below. Thus, one can infer that dependence asymmetry is **not induced** - an operationalization issue.

Tukey Simultaneous Tests for Differences of Means: Q5 (MFC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4a_Row - H4a_Col	0.143	0.359	(-0.889, 1.174)	0.40	0.999
H4b_Col - H4a_Col	1.071	0.389	(-0.046, 2.189)	2.75	0.069

Tukey Simultaneous Tests for Differences of Means: Q6 (MBC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4a_Row - H4a_Col	0.400	0.332	(-0.554, 1.354)	1.20	0.834
H4b_Row - H4b_Col	-0.346	0.385	(-1.452, 0.760)	-0.90	0.947

To further consider H4b, it is instructive to consider the cluster that it is a member of: H4b-H3b|H3a where H3b found support - because H4b is proximal to H3b and has a distal relationship to H3a. As can be seen in Figure 6.3 and the pairwise comparisons below, all members in this cluster have the same strength regarding BRC, MFC and MBC (p>.05).

Tukey Simultaneous Tests for Differences of Means: Q4 (BRC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4b - H3a	0.002	0.279	(-0.843, 0.848)	0.01	1.000
H4b - H3b	0.385	0.299	(-0.521, 1.290)	1.29	0.904

Tukey Simultaneous Tests for Differences of Means: Q5 (MFC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4b - H3a	0.046	0.280	(-0.802, 0.894)	0.17	1.000
H4b - H3b	-0.538	0.300	(-1.447, 0.370)	-1.80	0.622

Tukey Simultaneous Tests for Differences of Means: Q6 (MBC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4b - H3a	0.588	0.261	(-0.204, 1.381)	2.25	0.321
H4b - H3b	-0.615	0.280	(-1.465, 0.234)	-2.20	0.353

In view of its lack of difference between H4b and H3 on any of the components we can conclude that the *entire cluster*, including H4b, is being perceived as high interdependence. It appears that H4b is in fact in the region of the space of interdependence (Figure 3.15) refereed to as interdependent-like where JD>1 where joint dependence appears to dominate the effect of dependence asymmetry. It cannot be claimed that H4b is completely indistinguishable from H3 (high interdependence) but it does have a higher perceived joint dependence than H4a. Thus, as the comparisons below (and Figure 6.3) suggest is that H4b is 'H3-like' while H4a is 'H1-like'.

Tukey Simultaneous Tests for Differences of Means: Q4 (BRC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4a - H1a	-0.576	0.279	(-1.421, 0.270)	-2.07	0.437
H4b - H3b	0.385	0.299	(-0.521, 1.290)	1.29	0.904
H4b - H4a	-1.155	0.279	(-2.000, -0.309)	-4.14	0.001

Tukey Simultaneous Tests for Differences of Means: Q5 (MFC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4a - H1a	0.250	0.280	(-0.598, 1.098)	0.89	0.987
H4b - H3b	-0.538	0.300	(-1.447, 0.370)	-1.80	0.622
H4b - H4a	0.846	0.280	(-0.002, 1.694)	3.03	0.051

Tukey Simultaneous Tests for Differences of Means: Q6 (MBC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4a - H1a	0.575	0.261	(-0.217, 1.368)	2.20	0.351
H4b - H3b	-0.615	0.280	(-1.465, 0.234)	-2.20	0.353
H4b - H4a	2.117	0.261	(1.324, 2.910)	8.10	0.000

As shown above H4a is not different from H1a for any of the components and similarly for H4b. Thus, it appears that H4 is being perceived in the space of ID as shown in Figure 6.4 instead of the intended region (oval in Figure 6.4).

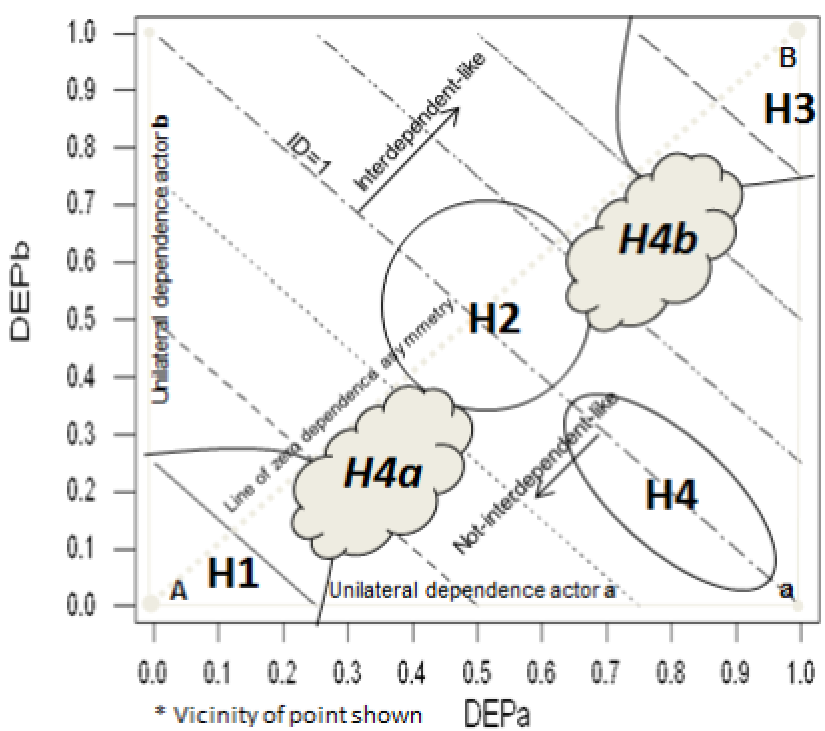

Figure 6.4 : H4 in the Space of Interdependence

As the preceding analysis has shown, it appears that dependence asymmetry is being masked by the effects of low or high joint dependence. Joint dependence - as approximated by Q4 - suggest that high IOT increases the perception of independence and the converse for low IOT.

Alternatively, based on the empirical evidence that DA was not induced, H4 is somewhat equivalent to H2 since JD for both are approximately the same - 1.14 and 1.11 respectively . The expectations and empirical evidence for H2a and H4a are also the same (III). While the empirical results for H4b and H2b are the same (I/II), the expectations for the two are attenuate (absorptive for H4b - II) and attenuate (transmissive for H2b IV). This may indicate that the moderate ID was perceived as closer to high ID but not quite high ID and hence the dilemma of overlapping (I/II) – II due to the pull toward moderate interdependence and I the pull from the high side (as in H3b). The effect would be that both H4b and H2b would be equivalent to each other regarding the components of interdependence and both similar, but not identical, to H3b. The pairwise comparisons shown below support this argument. Basically, H2b and H4b occupy the same space as shown by the region shown as 'H4b'in Figure 6.4 in the direction of, but not in, the space occupied by H3b. Note that H3b does have a stronger perceived task coordination requirement (Q6) than H2b/H4b meaning H3b is still being perceived as more interdependent.

Tukey Simultaneous Tests for Differences of Means: Q4 (BRC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4b - H2b	-0.184	0.279	(-1.029, 0.662)	-0.66	0.998
H3b - H2b	-0.568	0.279	(-1.414, 0.277)	-2.04	0.456
H4b - H3b	0.385	0.299	(-0.521, 1.290)	1.29	0.904

Tukey Simultaneous Tests for Differences of Means: Q5 (MFC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4b - H2b	0.075	0.280	(-0.773, 0.923)	0.27	1.000
H3b - H2b	0.613	0.280	(-0.235, 1.461)	2.19	0.356
H4b - H3b	-0.538	0.300	(-1.447, 0.370)	-1.80	0.622

Tukey Simultaneous Tests for Differences of Means: Q6 (MBC)

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H4b - H2b	0.246	0.261	(-0.547, 1.038)	0.94	0.982
H3b - H2b	0.861	0.261	(0.068, 1.654)	3.29	0.022
H4b - H3b	-0.615	0.280	(-1.465, 0.234)	-2.20	0.353

To summarize then, the statistical evidence indicates that dependence asymmetry is not induced (see page 151). Perhaps, dependence asymmetry is fully masked by [moderate] joint dependence – i.e., DA not induced – then for all practical purposes H4 is in the H2 region. This leads to other interesting research questions: when does dependence asymmetry matter? How does one induce dependence asymmetry despite the accompanying significant joint dependence? What is the effect of different levels of knowledge complementarity? Could other contingencies influence the effects of dependence asymmetry?

6.1.2 Cluster H1b-H2b

H2b (high IOT, moderate ID) is not supported and pairs with the supported hypothesis H1b (high IOT, low ID). A two sample t-test would merely indicate if the two were different or one greater than the other which sheds little insight into whether IOT is properly induced for H2b. Therefore, H1a, the counterpart to H1b is included in the analysis to provide the contrast; observe that both H1a and H1b have been ratified. If H1a has a significantly smaller mean value for the self-reported trust (6-point Likert scale) than that of H1b/H2b, then it is reasonable to infer that both H1b and H2b belong in the relatively high IOT category, while the H1a condition conveys an inducement of a relatively low value of IOT. The ANOVA and pairwise comparisons below ratify the above claim that IOT for H2b is in fact high. While the test validates the claim that high IOT condition in H2b is not violated, it is interesting to note that the high IOT state in H2b is significantly higher than the high IOT state in H1b further reinforcing the fact that H2b does indeed portray a high IOT condition.

One-way Analysis of Variance

```
Analysis of Variance for Trustc2
Source     DF        SS        MS        F        P
NewHypoc    2    206.22    103.11    77.31    0.000
Error     189    252.09      1.33
Total     191    458.31
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level       N      Mean     StDev  -+---------+---------+---------+-----
H1a        52     2.269     1.031   (--*--)
H1b        70     4.186     1.365                     (--*--)
H2b        70     4.843     1.002                            (-*--)
                                   -+---------+---------+---------+-----
Pooled StDev =    1.155           2.0       3.0       4.0       5.0

Tukey Simultaneous Tests for Differences of Means

Difference  Difference     SE of       Adjusted
of Levels   of Means       Difference    95% CI    T-Value   P-Value
H1b - H1a        1.916       0.211  (1.417, 2.416)     9.06     0.000
H2b - H1a        2.574       0.211  (2.074, 3.073)    12.17     0.000
H2b - H1b        0.657       0.195  (0.196, 1.118)     3.37     0.003
```

Therefore, attention is turned toward the operational inducement of interdependence. Since H2b pairs only with (H1b) a t-test is used in place of the ANOVA. Evaluation of inducement of interdependence is done using its three components, viz., BRC, MFC and MBC. The analysis follows below.

H2b (High IOT, Moderate interdependence) implies a lower level of independence (BRC measured by Q4) than in the condition portrayed by H1b (High IOT, Low interdependence). The t-test shown below ratifies this expectation ($p = .003$).

Two-Sample T-Test and CI: Q4 (BRC), Cluster H1b-H2b

* Predicted mean for Q4: H1b >H2b on Q4 (i.e. H1b is more independent)

```
Two sample T for Q4
HypoCLus     N      Mean     StDev   SE Mean
H1b         70      4.17      1.75      0.21
H2b         70      3.41      1.47      0.18
95% CI for mu (H1b) - mu (H2b): ( 0.22,  1.30)
T-Test mu (H1b) (H1b) - mu (H2b)>0 : T = 2.77  P = 0.0032  DF = 133
```

Next, the perception of partner influence (MFC) is evaluated for H2b and H1b. As can be expected, H2b is more susceptible to partner influence than H1b with which it pairs in the cluster (see Figure 6.2); the t-test below validates this expectation (p=.007).

Two-Sample T-Test and CI: Q5 (MFC), Cluster H1b-H2b

* MFC is smaller for H1b than H2b.

```
Two-sample T for Q5_1

HypoCLuster1b2b   N  Mean  StDev  SE Mean
H1b           70  2.61   1.55     0.19
H2b           70  3.27   1.54     0.18

Difference = μ (H1b) - μ (H2b)
Estimate for difference:  -0.657
95% upper bound for difference:  -0.224
T-Test of difference = 0 vs μ(H1b)-μ(H2b)<0: T-Value = -2.51  P-Value = 0.007
DF = 137
```

Since the H2b condition has a higher joint dependence than H1b, the need for coordination (MBC) should be higher than for H1b; the t-test shown below ratifies this expectation (p<<.01).

Two-Sample T-Test and CI: Q6 (MBC), Cluster H1b-H2b

* MBC is smaller for H1b than H2b.

```
Two-sample T for Q6_1
 HypoCLuster1b2b   N  Mean  StDev  SE Mean
H1b           70  2.87   1.76     0.21
H2b           70  4.04   1.49     0.18

Difference = μ (H1b) - μ (H2b)
Estimate for difference:  -1.171
95% upper bound for difference:  -0.715
```

```
T-Test of difference = 0 vs µ(H1b)-µ(H2b)<0: T-Value = -4.25  P-Value = 0.000  DF =
134
```

Low interdependence (H1b) entails higher independence than moderate interdependence (H2b); thus the BRC component of H1b ought to be comparatively stronger than that of H2b. As was previously shown, this does appear to be the case ($p=.0032$). Thus, it appears that when inter-organizational trust is high, the effects of moderate levels of joint dependence on KEB are distinguishable from low joint dependence - KEB promote/attenuate vs. retard - but not as expected.

6.1.3 Cluster H1a-H2a-H4a

The last tight cluster is composed of three low IOT hypotheses - H1a, H2a and H4a (see Figure 6.2); all three hypotheses have been empirically ratified. While there is no unexpected finding here to be examined, an intriguing insight seems to emerge from this cluster. It appears that when IOT is low knowledge exchange behavior is indifferent across low and intermediate levels of JD-dominant interdependence, and DA-dominant interdependence; in all these three conditions KEB is ‘retarded’ when IOT is low. Only when the level of interdependence is high KEB is not retarded even when IOT is low. How can one say that this hypotheses pattern (H1a-H2a-H4a) is indeed related to interdependence and not IOT? The ANOVA presented below tests for the difference in the trust level across these the three hypotheses conditions. If the test fails to reject the null hypothesis that there is no difference in ‘trust’ across H1a, H2a and H4a, one can infer that the effect has to be due to interdependence. The ANOVA results shown below ratifies the notion presented.

One-way Analysis of Variance

```
Analysis of Variance for Trustc3

Source      DF        SS        MS        F        P
NewHypoc     2     4.345     2.172     2.19    0.115
Error      171   169.793     0.993
Total      173   174.138
                                   Individual 95% CIs For Mean
                                   Based on Pooled StDev
Level        N      Mean     StDev ---+---------+---------+---------+---
H1a         52    2.2692    1.0312              (----------*----------)
H2a         52    2.1923    0.9505           (----------*----------)
H4a         70    1.9143    1.0035 (---------*--------)
                                   ---+---------+---------+---------+---
Pooled StDev =    0.9965            1.75      2.00      2.25      2.50

Tukey Simultaneous Tests for Differences of Means
Difference  Difference       SE of                             Adjusted
of Levels     of Means  Difference        95% CI      T-Value   P-Value
H2a - H1a       -0.077       0.195  (-0.538, 0.385)     -0.39     0.918
H4a - H1a       -0.355       0.182  (-0.786, 0.076)     -1.95     0.129
H4a - H2a       -0.278       0.182  (-0.709, 0.153)     -1.52     0.282
```

This was theorized in this research and appears in the three levels of interdependence in the cluster: low and medium JD-dominated interdependence, and high dependence asymmetry. The predicted and actual KEB response for these three conditions is ‘KEB retard’. The fact that H1a (low ID), H2a (moderate ID) and H4a (high dependence asymmetry) cluster seems to reinforce the conceptualization that when inter-organizational trust is low, only a high level of interdependence can supplant the absence of trust. This also suggests that, from a knowledge exchange perspective, low and moderate levels of joint dependence or high dependence asymmetry are indistinguishable when IOT is low - observe the KEB response is the same (KEB retard) under all three conditions.

6.2 Summary of ex post analysis and implications

The ex post analysis described above provides insight as to whether the lack of empirical support for H2b, H3a and H4b was due to operational issues (i.e. lack of inducement of the theoretical variables) or conceptual gaps. Table 6.1 summarizes the insight gained from the analysis and whether the lack of support is clearly a operationalization issue or a suspected inadequacy in conceptualization.

Table 6.1: Summary of Findings Regarding Unsupported Hypothesis

Hypothesis	**IOT***	**ID**	**Basis for exploration**	**Notes**
H2b	High	Moderate	Conceptual	When IOT is high, the effects of moderate interdependence is distinguishable from low interdependence; nonetheless, the influence on KEB is not as predicted. Since the operationalization of IOT and interdependence are empirically ratified, the issue requires conceptual explanation.
H3a	Low	High	Conceptual	Statistical evidence suggests that IOT and interdependence are correctly induced. However, the need to coordinate appears to be perceived more strongly when trust is high than when it is low despite the actual incentive structure. Absence of 'reciprocity norm' in the conceptualization may be the key to seek further conceptual clarity.
H4b	High	High DA	Operational	Inducement of IOT is empirically ratified. Dependence asymmetry (DA) is not detectable for either H4a or H4b. H4b appears to be between moderate and high joint dependence - between H2 and H3 - while H4a appears to be between H2 and H1.
* Empirical evidence suggests that inter-organizational trust (IOT) is properly induced for all three unsupported hypothesis conditions.				

The motivation for this study was Kim, Umanath, Kim, Ahrens & Kim (2012) where they found a result that suggested that increasing trust tended to reduce KEB - the opposite of what was expected. This work does validate their *ex post* speculation that perhaps 'interdependence' which they didn't model is the contingency capable of explaining their unexpected result. In addition, this research also found some unexpected results for some of its other hypotheses. The lack of support deriving from operational issues alone (H2b and H4b) indicates further fine-tuning of the lab procedure which is discussed in the next section. There are indications, however, of conceptual limitations also (e.g., H3a). While alternate speculation(s) for the unexpected results for H2b and H4b are not immediately visible, the next section draws from the extant literature to propose a possible extension of the theoretical basis of this work that can be of value in exploring this further.

Knowledge exchange behavior can be investigated using different conceptual lenses. For example, Kim et al (2012) used social capital and transaction cost economics. This work juxtaposed game theory and relational view as opposing viewpoints augmented by social exchange theory and social capital as previously described. Seeking theoretical clarity for some of the unexpected results, perhaps broadening the theory base of this work while retaining its demonstrated explanatory power is, perhaps, necessary. To that end, perspectives using the same or similar constructs are sought.

A useful framework for extending this work can be found in Palmatier, Dant, & Grewal (2007) who investigated drivers of inter-organizational relationship performance using four perspectives: commitment-trust, dependence, transaction cost economics and relational norms. They assessed inter-organizational relationship performance in terms of sales growth, overall financial performance, cooperation and conflict. Of these, cooperation is the most related to KEB since it can be thought of as "the coordinated and complementary actions between exchange partners to achieve mutual goals" (Palmatier et al, 2007).

In comparing the four perspectives, the following constructs are used either as antecedents or mediators to inter-organizational relationship performance: customer and seller relationship-specific investment, seller opportunistic behavior, interdependence, dependence asymmetry, relational norms, communications, commitment and trust.

Of interest in explaining the unsupported hypotheses are the constructs shared with the conceptual basis of this work and new perspectives. For example; the commitment-trust and relational norms perspective used in (Palmatier et al, 2007) fall under the rubric of social exchange theory while the transaction cost economics and dependence perspective are economics based views. This work, like Palmatier et al (2007), employs perspectives that come from either a social exchange or economic domain. Figure 6.5 represents these perspectives in a Venn diagram showing constructs which are broadly shared and related to constructs used in the current research.

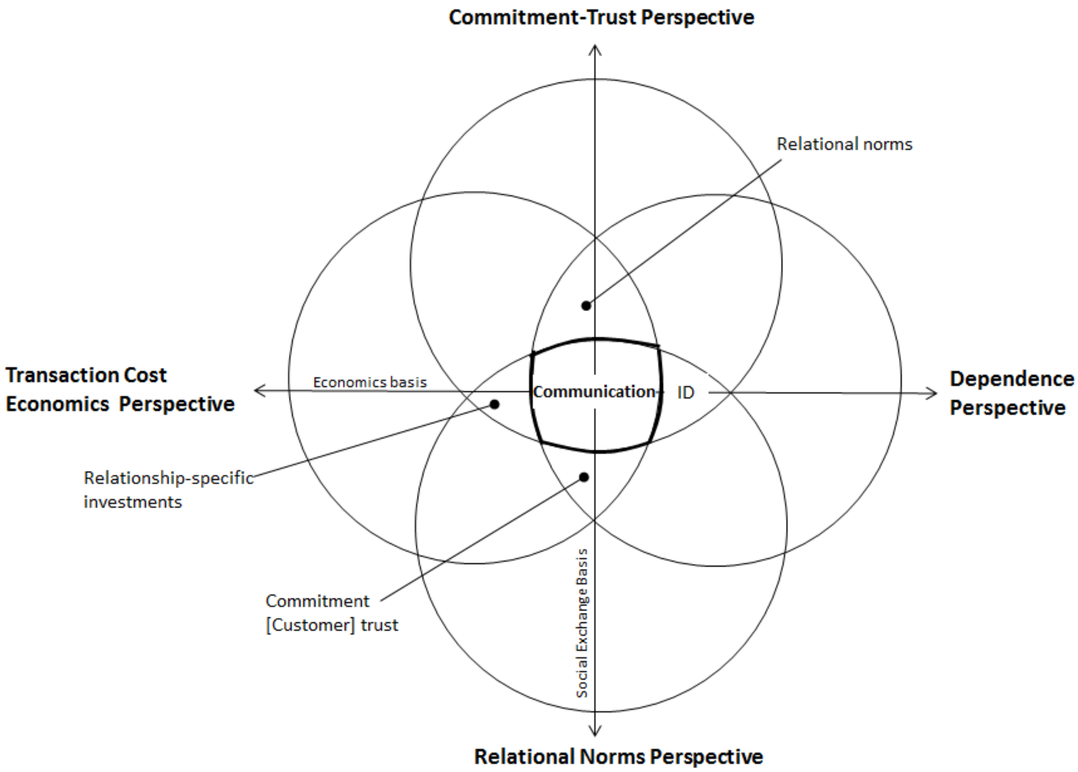

Figure 6.5: An Expanded Theoretical Base

Communications is an antecedent to inter-organizational relationship performance (including cooperation) in all four perspectives. *Communications* is taken to be "prompt, timely and well understand" and is important because it drives trust and relationship specific investments (which drive commitment) (Palmatier et al, 2007). Communications is not the same as the common knowledge assumption central to this research because common knowledge simply denotes that both parties know the same information. It does not address actor intentions, beliefs, and strategies - in other words what an actor intends to do with this shared knowledge. This is the purview of communications.

Commitment is " an enduring desire to maintain a valued relationship" (Moorman, Zaltman & Deshpandé, 1992). Commitment has a central role in game theory because it reflects an incentive structure that makes it disadvantageous for an actor to *not* execute on its intent. A widely cited example is that of Cortez, the explorer, who burned his ships after landing in the new world to dissuade the crew from turning back. This research already captured commitment in some of the models used because deviating from a prescribed action would have a cost exceeding the potential benefit.

Relational norms can be thought of as a belief system shared in a relationship that governs the interaction between partners (Palmatier et al, 2007). This governance can be explicit in the form of contracts and formal governance mechanisms but at a deeper level it is tacit.

Referring again to the Figure 6.5, one will note the central role of communications. This has both theoretical and operational implications. Conceptually, communication influences relational norms and commitment which are already part of this research. This in turn can influence perceptions of other constructs such as trust orientation or the requirement to coordinate on a task (MBC). With regards to the latter (task coordination) communication can help disentangle trust from MBC.

The current research demonstrates the central role of interdependence and trust in KEB. The framework already developed in this research is extensible and could include communication and commitment more explicitly. Relational norms can be the consequence of enhanced communications and commitment. An expanded theoretical basis would also require a deepened methodological approach which would explicate the new and current constructs in the research model more perceptibly to a human participant - a rich opportunity for future research.

7. Conclusion

This research further explicates the conflicting role of trust by supporting the assertion in Kim et al (2012) that the influence of trust on KEB is contingent on other factors. It was also found that trust does not have an unequivocal influence on the decision to share knowledge-sometimes trust really does *not* matter. But the role of trust is not refuted by this research. Does trust matter? Well, the conclusion of this research is “It depends!”.

The table below is a summary of the observed KEB responses under the various conditions of IOT and interdependence. A key takeaway is that when interdependence is low or high the role of trust is unimportant. This is because the cost of the exchange dominates the decision criteria. The moderate and asymmetric interdependence cases appear to be where trust can have a decisive role.

Table 7.1: Implications of Observed KEB Response on ID and IOT

Observed KEB Response

		Interdependence			
		Low	**M, DA**	**High**	
Inter-organizational trust	**Low**	H1a	H2a, H4a	H3a	**Influence of Interdependence**
		Re	Re	Pr/Att2	Yes (ID=H)
	High	H1b	H2b,H4b	H3b	
		Re	~Re	Pr	Yes
		No	Yes	No	
		Influence of IOT			

Interestingly though, interdependence itself appears to be contingency based. For example, when IOT is low, only high interdependence seems to facilitate knowledge exchange. When IOT is high, though, it appears the decision to exchange knowledge is very sensitive to interdependence. Even though two high trust conditions (H2b and H4b) were not supported, they still yielded responses different from the low and high interdependence cases.

In inter-firm relationships the underlying context is primarily economic gain. This can arise from a relational basis where value is generated due to an unreplicatable relationship or because there is an alignment of incentives between the member firms.

The role of trust has become almost uncritically accepted as necessary, indeed desirable to promote economic well being. This research has shown that the role of trust is contingency based. While trust matters, it does not matter always; there are times when trust may not be relevant in a dyad. This doesn't mean that, say, cooperation gets precluded. This has implications for both academics and practitioners.

Trust is costly to develop and can easily be lost. Yet the benefits from successful collaboration need not be lost if other conditions can promote a successful exchange and mitigate the risks associated with relying on trust. Conditions can exist that facilitate a relationship that is mutually beneficial in the absence of trust, or even in the presence of mistrust. There is an extensive body of research investigating the role of trust in promoting relationships including the antecedents and characteristics of trust. In stark contrast, there is a dearth of research investigating cooperative behavior in the absence of trust. A healthy skepticism about the role of trust in dyadic or network engagements can help broaden the scope of research in this domain.

This research has taken a small step along these lines by showing some evidence for the role of interdependence in rendering trust unnecessary. In the process, this research also observes that interdependence unless really high may not matter under low trust conditions. Other variables like commitment, communications, or relational norms may also soften or eliminate the effect of trust on knowledge exchange behavior. All these are fodder for academic inquiry.

For practitioners it is hoped that this research provides a framework for developing successful cooperative relationships that are less subject to the vagaries and fragility of trust which can take an immense investment of time and resources to develop. Rather than profitable relationships evolving as a consequence of trust, perhaps trust can be developed as a consequence of successful relationships. As Deng Xiaoping once said when China and the United States established firmer diplomatic relationship after the death of Mao Zedong, 'cross the river by touching the stones'. By understanding a potential partner's intentions - as this research sought to study - it may be possible for firms to initiate mutually profitable relationships that are not reliant on good intentions alone.

8. Limitations and Future Research

8.1 Limitations

The findings in this research seem to suggest that the effects of trust on knowledge exchange are subject to the influence of contingent factors. Using an expanded theoretical perspective, we were able to bring some illumination to the equivocal role of trust. However, this work is not without its limitations.

The original experimental method for this research involved

- a real-time multi-period turn-based game
- where two anonymous human participants played each other in the context of a scripted supply channel environment.

Unfortunately, in a real-time multi-period game there are issues associated with (1) evolution of trust, (2) players engaging in non-strategic gamesmanship (e.g. trying to 'beat' the other player) and (3) other learning effects.[12] These confounds are well documented in the literature. Papers referencing repeated games noted:

- Dynamic issues (e.g., learning effects).
- non-contingent strategies resulting in behavior equivalent to one-time game (Non-contingent strategy arises when a player's actions are not conditioned on its partner's actions. The challenge is to induce a contingent response).

While, by definition, a dyad is best operationalized with two participants, it is critical that individual differences in the pair be accounted for in the data analysis. In addition, increased sample size poses a practical constraint.

It was felt that attempting to control for these potential confounds would have been a distraction from the research intention; plus, the research scope would have been unmanageably large. Thus, a one-time game, with enhancements was chosen. Most of the benefits of a repeated game were retained by

[12] I would like to thank my dissertation committee for alerting me to these pitfalls and helping me in trimming the scope of the research to a manageable research project.

- providing appropriate timeline of past interactions commisurate with each scenario and payoff structure;
- incorporating a richer narrative where both the current business environment is described and a history of the past relationship between the two firms is described.
- by subtly having a participant play both members of the dyad in a random and non-detectable order - an unobtrusive operationalization.

In spite of these mitigations, the current experimental design is unable to:

- study learning/dynamic effects.
- fully replicate a historical context.

The dynamic effects include, but are not limited to, the effects of non-strategic play whereby participants react to considerations beyond the immediate context. Generally this is undesirable because it can be a theoretical confound, especially if the players are trying to 'beat' the scenario or other participant(s). Nevertheless, a carefully crafted experimental design can minimize, however not eliminate, this effect. This would enable other effects not studied in this research to be investigated, for example the evolution of trust under different incentive structures.

Additionally, dynamic and learning effects themselves augment the historical context because the participants would actively be creating this history rather than internalizing a constructed history as done in this research.

Another limitation is the use of a single game to model each hypothesis resulting in either joint dependence being held constant and dependence asymmetry varied (e.g. H4a) or dependence asymmetry being held constant (in fact, near zero) and joint dependence varied (segment A-B in the space of ID Figure 3.15). If a succession of games could be used for each hypothesis it would be possible to model paths in the space of interdependence rather than fixed regions as is currently the case. This could allow for the effects of path dependencies on KEB to be modeled.

Common knowledge is the condition where both actors know the incentive structure for themselves and their partner. While this broadly reflects most realistic supply channel dyads, there can be situations where the members do not know *for sure* what incentives their partner is reacting to. This can be the case especially in new relationships. The effect of a lack of common knowledge is that neither actor knows for *certain* what game they are playing. This means that an actor must make decisions based on beliefs about its partner as opposed to certainties. Concomitantly, this research was unable to explore *ab initio* relationships.

Lastly, trust was assumed to be the same for both members in the dyad (i.e. low/low or high/high). It is possible, indeed certain, that relationships exist where one member trusts a partner who does not trust it in return. This need not be due to interpersonal or hostile motives but instead due to instrumental reasons or lack of common knowledge as previously described. Asymmetric trust states would likely result in markedly different interactions than what could be investigated in this research.

These limitations essentially serves as the springboard for extension of the research as future research projects.

8.2 Contributions

This research sought to answer two research questions:

R1: What is the role of inter-organizational trust in knowledge exchange behavior?

R2: What contingencies mediate/moderate impact of inter-organizational trust on knowledge exchange behavior?

The role of inter-organizational trust on knowledge exchange behavior has been found to be conditioned by interdependence thus validating the speculation in Kim et al (2012). However, the findings of the originating study is extended by also addressing the second research question. Interdependence, like trust, is not a monolithic construct whose effects on KEB are unequivocal. Rather, interdependence, and its effects on knowledge exchange, can be unpacked.

The work has contributed to the understanding of knowledge exchange by demonstrating that interdependence is composed of components which, in combination with trust, influence knowledge exchange behavior. In addition, it is possible that the 'reciprocity norm' may have been demonstrated empirically in the context of a quantitative model. Previous renditions of this idea have been mostly limited to a conceptual visualization (e.g. Blau, 1964).

Methodologically this work has contributed to the research domain by demonstrating an alternative to the choice of a repeated vs. one-time game. It is now possible to capture the 'shadow of the future' of a repeated game without the issues posed by a repeated game.

Another contribution to the research domain is the application of a broad array of analytical tools to provide a deeper insight into the data than a focused treatment alone could provide. This was principally enabled by using a vector representation to link two individual-level responses - one for each member of the dyad - to form a dyad-level response - the level of analysis of the focal phenomenon. A response vector can be treated either as a quantitative variable (i.e. response angle) or a categorical variable (i.e quadrant). Thus, both statistical and data mining tools could be used to gather deeper insights into both knowledge exchange behavior and the underlying behavioral components. Such an approach appears to be a novel one in the empirical domain of behavioral research in business - no other reference could be found for this type of transformation providing inventive value for the adoption of the computational technique.

The unsupported hypotheses also contribute to the understanding of knowledge exchange behavior. For example, the elevated perception of the need for task coordination when trust is high when compared to a low trust state and the same incentive structure. Also, it appears that dependence asymmetry can have effects apart from pure-conflict; it can, under certain conditions, mimic a more balanced but higher joint-dependence relationships. Essentially, while the individual actors' dependences on the relationship may be different, it may not matter if the less dependant actor has a high enough dependence on a relationship - i.e., the independent actor may still experience the effects of joint dependence; when JD is high enough, the effect of DA may be masked.

While the findings in this research contain both novel and banal findings, the limitations of this research leave some findings unstudied. Next, a vision of a future research direction building on this work is articulated.

8.3 Future Research

The scope of this dissertation has deliberately limited the research to examination of focused areas in the the space of interdependence (see Figure 3.15). The region in the space of interdependence where both JD is high and DA is non-zero appears to have been encountered but this is an empirical finding that was not considered conceptually in the present research. This region could best be explored by having a series of game matrices played in successively where each iteration is a slight transformation of a game matrix from the previous iteration. In the original theory of interdependence perspective (e.g. Kelley & Thibault, 1978) these transformation reflect a participant's changing perception of the incentive structure. Unlike a static representation whereby a single incentive structure (i.e. resultant matrix) is experienced, the participant would see a slightly changing structure depending on their previous decisions. This is similar to some standardized tests such as the GMAT which make a question more/less difficult based on the prior response. In this context, successive transformations of game matrices reflect a participant's ‘journey’ through the space of interdependence.

Next, a basic premise of this research is what is referred to as "common knowledge assumption" - i.e., it is assumed that both actors in a dyad know what its partner's trust state and incentives. The 'common knowledge' assumption means that both members know the payoff structure both for itself and the partner. If, however, this were not true - i.e., if the 'common knowledge assumption is relaxed' - a different dynamics in a dyad is possible. That is, 'inadvertence' surfaces where the actors are not sure about the trust state (and intended action) and/or incentive structure of its partner. This means there is uncertainty about how a partner will react once an action is detected.

A classic example is the 'recicropocal fear of surprise attack' scenario (Schelling, 1961). In that example, Schelling used the example of an armed robber breaking into a home and being confronted with a similarly armed home owner. The robber's intention is to steal, not kill. The homeowner does not want to kill the robber either but is fearful that the robber may kill him first assuming that he, the owner, may fire first. The robber knows that the owner may have this fear; so the robber ought to be motivated to shoot first . . . and so on.

In the case of trust, the lack of common knowledge requires a member of a dyad to act on its belief regarding how its partner views the relationship even if both know the incentives; whether it is low trust and therefore act from a short-term perspective or of a trusting long-term point of view. In essence, each actor must act on its belief about its partner's intentions. The beliefs held by an actor need not be naive but based on past interaction. Additionally, there is a class of games in game theory called signalling games whereby actions convey intent. Specifically, a *signal* is costly to a sender but not to the extent that it precludes the message being sent if it is 'sincere'. For example, Spence (1973) describes how a college degree is a labor signal of intelligence. For one with the requisite intelligence this signal would be costly, but not so much as it would be if one lacked the innate ability that this signal presumably represents.

A primary underpinning of this research is knowledge complementarity which is held constant at a 'high' level because knowledge interdependence may not be an issue with 'low' levels of knowledge complementarity (Kim, et. al 2012). It is possible to further characterize knowledge complementarity to reflect different aspects relating to the relative contributions of knowledge required from each dyad member. Specifically, a 'unit' of knowledge need not be equivalent and in fact may be considered as a 'a vital few vs trivial many' like the Pareto principle in quality improvement circles. Some interactions may require one partner to contribute a small amount of vital information whereas its partner contributes voluminous low value, but necessary, knowledge. Appendix D presents some possible concepts that can be developed leveraging earlier, but largely abandoned, research on attention management.

Finally, supplementing 'theory testing' with 'effect testing' is a powerful way of triangulation in any domain of research. To that end, a survey research to study the research model in the field is in the works.

It is hoped that this research is a rubric for further study and inform a broader discussion on knowledge exchange behavior.

"He who would learn to fly one day must first learn to walk and run and climb and dance; one cannot fly into flying. " ― Friedrich Nietzsche

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Appendix A

Calculating row and column indices

The matrix decomposition technique used (Kelley & Thibaut,1978) enables Social Exchange Theory and Game Theory to be linked because the normal form game (resultant matrix) used in game theory to model interactions also has patterns of interdependence; the purview of SET.

In addition to decomposing the game matrix into behavioral components – bilateral, reflexive control, mutual fate control and mutual behavioral control - the technique also provides indices from which dependence can be quantified. While the reader is directed to the reference for the derivation of the formulae associated with the decomposition technique, this section will show how it is applied in this research. Let Figure A.1 showing a Prisoner's Dilemma game be an illustrative example.

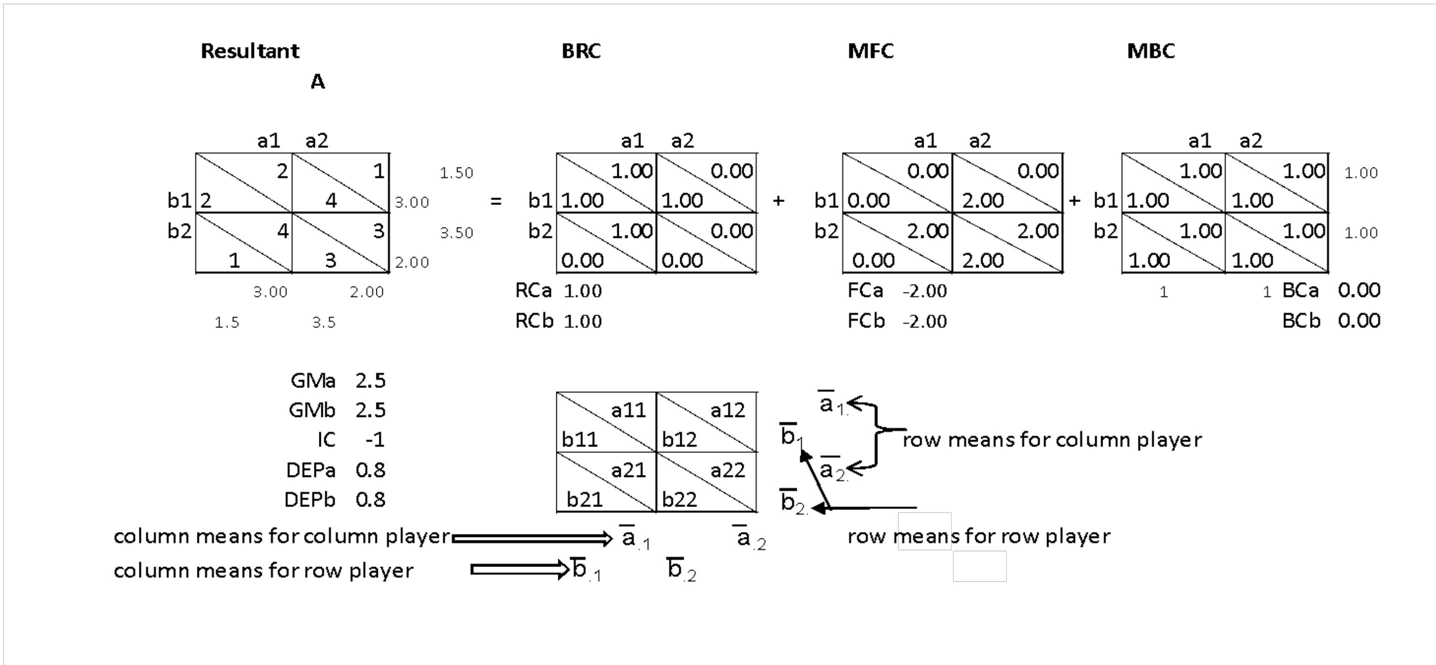


Figure A.1 Row and column means for resultant matrix

The components of interdependence (SET) aggregate into the overall game matrix (i.e. resultant). Let b_{ij} be the elements of the resultant matrix for the row player; the entries on the lower diagonal. a_{ij} are the entries in the upper diagonal of the resultant matrix for the column player. The row and column means for each player is indicated in Figure A.1 and calculated using equations 1 and 2.

The row average for the column player is given by:

$a_{x.} = ( ) / 2$ (1)

Where x{1,2} and i {1,2} and the '.' notation in the subscript means across the range of that subscript.

Similarly, for the row average for the row player:

$b_{x.} = ( ) / 2$ (2)

The column average for the column player is:

$a_{.x} = ( ) / 2$ (3)

The column average for the row player is:

$b_{.x} = ( ) / 2$ (4)

From the row and column averages calculated in equations 1-4 it is possible to calculate the indices of reflexive, fate and behavior control for each player individually. For player x the indices are;

RC_x ; index of reflexive control.

FC_x; index of fate control.

MC_x ; index of behavior control

Additionally, it should be noted that value of any of these indexes for player x need not be equal to player x+1; in asymmetric matrices they will not be equal. Let the index of reflexive control for the column player, RC_{col}, be given in equation 5 as:

$RC_{col} = a_{.1} - a_{.2}$ (5)

Or,

$RC_{col} = 1.00 - 1 .00 = 0.00$

And likewise, for row:

$MC_{row} = a_{1.} - a_{2.}$ (8)

Or,

$MC_{row} = 1.00 - 0.00 = 0.00$

Likewise, for the row player, RC_{row} is given in equation 6 as:

$RC_{row} = b_{1.} - b_{2.}$ (6)

Or,

$RC_{row} = 3.00 - 2.00 = 1.00$

The index of fate control, FC, for the column player is given in equation 7 as:

$FC_{col} = b_{.1} - b_{.2}$ (7)

Or,

$FC_{col} = 1.50 - 3.50 = -2.00$

It should be noted, that FC unlike RC and MC, is an index of a change *to* that players outcome imposed by the other players action. This is in contrast to the other indices which are measures of the consequence of *that* player's action. This is in keeping with the original development found in the reference work.

The index of fate control on the row player is given by:

$FC_{row} = a_{1.} - a_{2.}$ (8)

Or,

$FC_{row} = 1.50 - 3.50 = -2.00$

The indices for behavioral control, MC, are different from the calculation of RC and FC; also keeping with the reference work. Instead of using the row/column average, the index is calculated from the entries in row1/column1; the reference cell (upper left quadrant in the resultant). This is because behavioral control, unlike fate control, depends on the actions of *both* actors. Thus, if an actor selects an action, the payoff of its partner will be influenced by that and what that player does if behavior control is present; that is BC is not zero. If BC is positive, then that actor has an interest in coordinating with its partner. Conversely, if BC is negative, then that means the actors actions are interfering with each other; their MBC matrix is not correspondent (there preferences are incongruent).

The index of behavioral control for the column player, MC_{col}, is given by:

$MC_{col} = a_{11} – a_{21}$ (9)

Or,

$MC_{col}= 1.00 – 1.00 = 0.00$

$MC_{row} = b_{11} – b_{12}$ (10)

Or,

$MC_{row}= 1.00 – 1.00 = 0.00$

This example illustrates that while the MBC matrix has nonzero entries that the index of BC for both actors are zero. This means that this relationship is trade-like where either actor can punish/reward the other due to the dominance of the MFC matrix. Thus, unlike a coordination game where the actors merely wish to avoid interfering with one another, this relationship will be dominated by a reciprocal exchange of reward or punishment.

With these three indices each actor's dependence, DEP_x, on the relationship can be calculated by equation 11:

$$DEP_x = (FC_x^2 + BC_x^2) / (RC_x^2 + FC_x^2 + BC_x^2) \qquad (11)$$

The derivation in the reference work was conceptually similar to an ANOVA applied to the resultant matrix. The denominator in equation 11 represents the total variance for that actor when interacting with the other through the resultant matrix and the numerator is variation with no reflexive control; the dependence on the relationship. The index can range from zero – independent – to 1.00, total dependence. Likewise, the dependence on the relationship need not be equal for each player. Indeed, in the presence of dependence asymmetry the index is different.

In an extension of this work, we use the definition of interdependence found in Kumar et al (1995) to be the sum of the individual actor dependence. This allows us to relate dependence – an individual measure of need to be in the relationship – to interdependence which is the shared need. Also using the index DEPx, we define dependence asymmetry to be the difference in value between the actors in the dyad.

Appendix B

Hypothesis and the Experimental Design

Comments

DEPx:

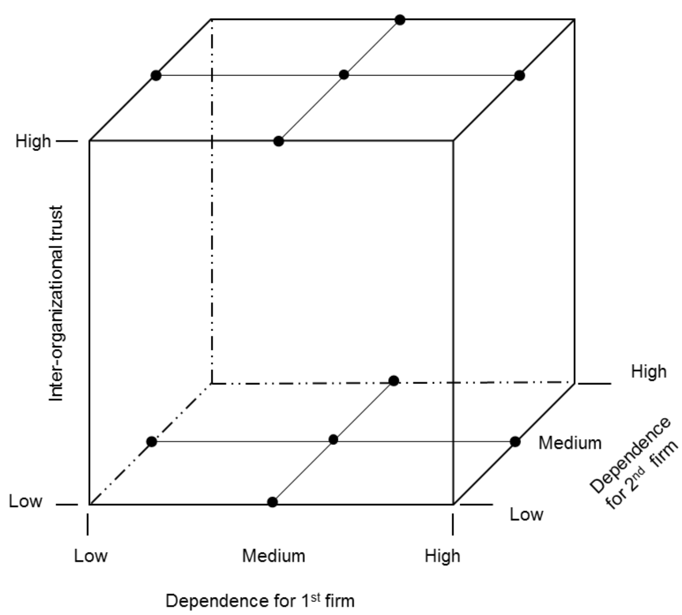
Low =0

Medium=.5

High=1.0

DA = |DEPa –DEPb| ; DA=0 no dependence asymmetry , DA=1 is unilateral dependence asymmetry.

ID = DEPa + DEPb ; IC=0, no interdependence, IC=2 total interdependence



Appendix C

A Regime Diagram

A response surface of KEB over two independent variables since the two individual actor dependence values can be combined to make interdependence or dependence asymmetry. The response surface methodology is an appealing and intuitive visual tool and has been used in similar research (e.g. Gefen & Pavlou, 2012). Another approach is to use the test data to create what are called 'regime diagrams'. An example is shown in Figure 1.11 from calculated results.

Each actor has a choice to either exchange knowledge in response to his or her partner providing knowledge or not respond. For the row actor (the b entries in the matrix) it can evaluate the present value of continued exchange at b11 for infinite duration of the one-time payoff of b21 ('suckers payoff') followed by b22, the payoff for no knowledge exchange. This is called the 'grim strategy' whereby if one actor defects the other withholds cooperation forever. Thus;

$$\frac{b11}{1-\delta} = b21 + \frac{\delta b22}{1-\delta}$$

Where δ is the discount factor. It is how much an actor values a future payoff stream. For example, if it is 0.0 it would mean only the current period payoff has value and the future is discounted. In our case, if δ=0.0 it would mean that the benefit of the cooperation payoff, b11, is so great that even if future cooperation broke down it is still

	KE+	KE-
KE+	a11 b11	a12 b12
KE-	a21 b21	a22 b22

equivalent to the suckers payoff. Thus, for δ=0.0 knowledge exchange is almost certain to occur because even a single turn of cooperation is equivalent to the present value of the suckers payoff please the future stream of no KEB payoffs.

The figure is a regime diagram for δ=0.0 where knowledge exchange is always the most beneficial strategy. The horizontal axis is the ratio of FC/BC the control value for the MFC and MBC matrix respectively. If the ratio is positive it means the MFC-MBC pair is concordant; the coordination requirements of the task are beneficial to the actor. The index of correspondence is the degree to which outcomes on the resultant matrix are not in conflict between the two actors. The region of high inter-organizational trust is the upper right quadrant where the MFC-MBC is concordant and the index of correspondence is positive as previously developed. The other three quadrants are for low trust for different reasons.

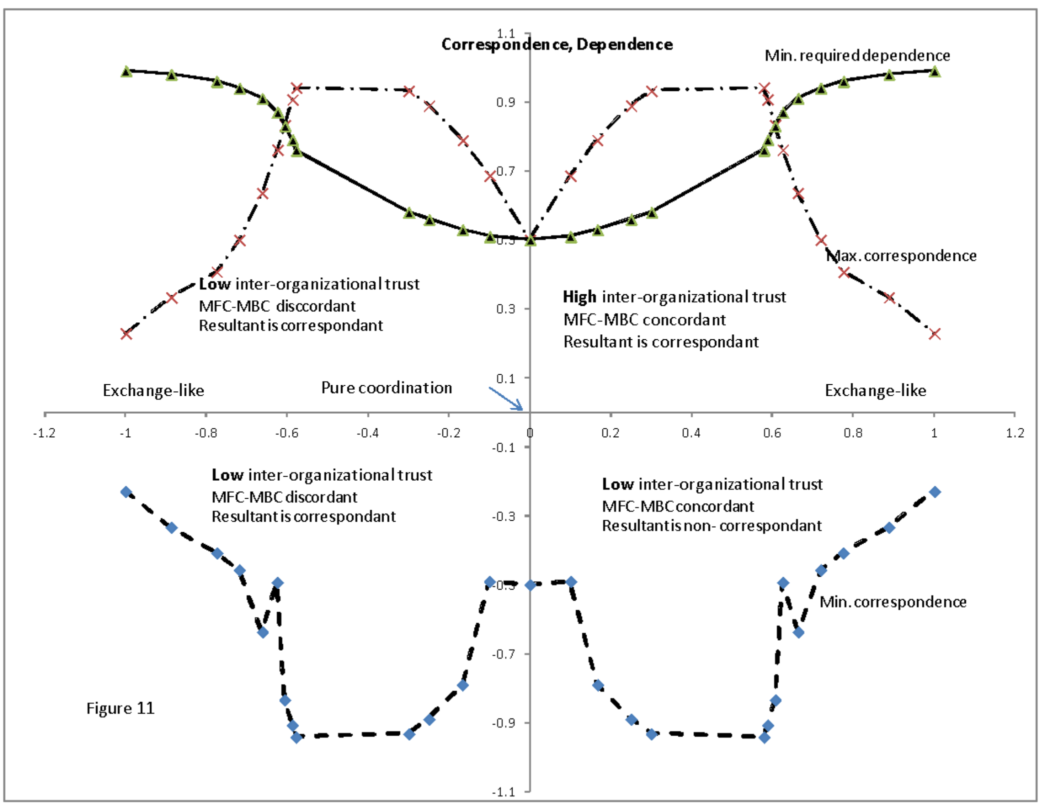


Figure 11

The curve for minimum required dependence is the lowest value of actor dependence that would be expected to be required to induce KEB for the given ratio of FC/BC. The ratio FC/BC is the relative influence of the mutual; fate control matrix compared to the mutual behavior control matrix. If BC=0 then the relationship is a pure exchange whereas if FC=0 it is one of pure coordination. The curves for IC bound the maximum and minimum permissible correspondence and still expect KEB to occur.

Appendix D

Characterizing KC

In evaluating the propensity to form a relationship, a comparison of the actor's knowledge to be shared must be made. In fact, knowledge is a tradable good whose value lies both in 'existence' and in 'trade'. While there are many reasons for two firms to enter into a relationship (e.g. joint production, product promotion, etc) we restrict our attention to the intellectual property domain - knowledge sharing in a supply chain channel.

In establishing a relationship, the characteristic of the knowledge that may determine the value as a tradable commodity is what has been called knowledge complementarity. Knowledge complementarity was extended by Kim, Umanath, Ahrens & Kim (2012) in their work which we characterize as the adjoining of two distinct bodies of knowledge such that the agglomeration is super-additive; the combined knowledge set has a higher semantic value than the simple additive knowledge of the parts. KC may take three forms in a relationship: channel-like, firm-like and partially substitutive. As a prelude to a more detailed description, let us introduce each at a conceptual level first. *Channel-like* KC is a shared body of knowledge that exists only within the context of the dyad. Each actor contributes a knowledge subset that in combination creates a channel specific capability. *Firm-like* KC is a body of knowledge that is wholly possessed by one or both actors, as a self-contained body of knowledge, whose presence in the channel enables an activity by the cooperating party. Both parties could use their knowledge base unilaterally but entering into the exchange can create capabilities beyond the immediate intent of the focal channel relationship. *Partially substitutive* KC is intermediate to channel-like and firm-like and thus represents a more generalized case. Here each actor's knowledge could be substituted within the channel but at differential marginal cost to both actors. Further, each actor's contributed knowledge could be a sole knowledge input to the process at a degraded level of knowledge exchange for the dyad or cost to the actor. The degenerate case is *no-KC* where the knowledge available from one of the firms is irrelevant to the joint capability of the dyad.

We also further extend the KC concepts as developed in Kim, Umanath, & Kim (2010) by adapting the framework presented in Navon & Gopher, (1979) where a task draws on multiple resources in its execution. Figure 2 depicts four KC conditions where knowledge supplied by both actors contributes to a level of knowledge, the isoquants[13]. The axis corresponds to knowledge contribution by each actor as measured by a proximal indicator, for example the investment value of the contributed knowledge, which signifies each actor's contribution to the exchange.

The measurement of knowledge exchanged could be either financial or operational indices. Indeed, measuring knowledge is an entire domain in its own right. However, for our purpose it is not essential *how* KEB is measured; only that the measure is consistent for both members in the dyad exchanging identical types of knowledge.

Types of Knowledge Complementarity

The classification of KC is necessary because it affects the nature of the exchange process. Specifically, the characteristics of KC will influence the pattern of interdependence in the dyad and hence the payoff structure associated with the relationship.

[13] Isoquants are lines of constant value. For example, z=f(x,y) where z=constant and x and y vary

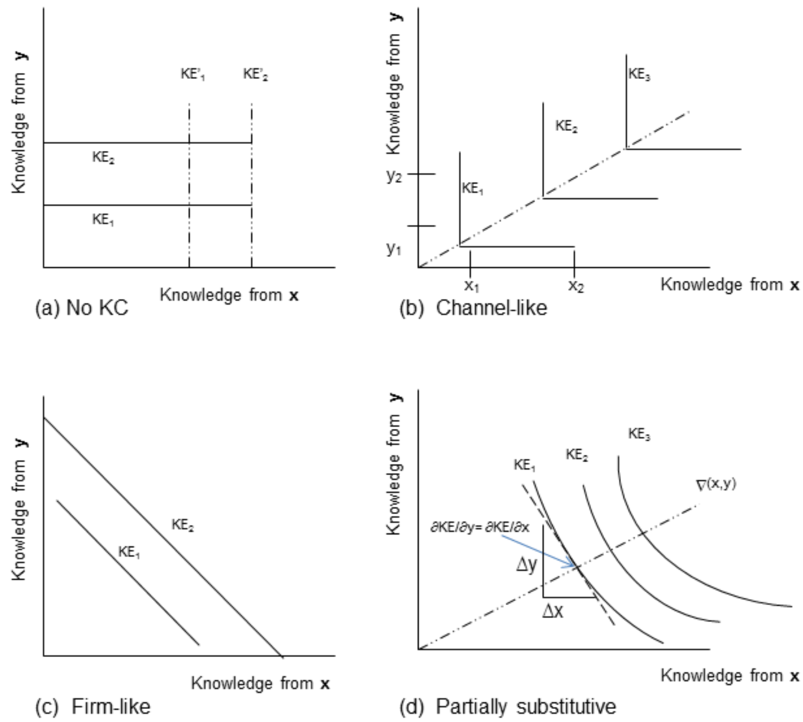


Figure D.1[14]**:** Isoquants for knowledge exchange under various conditions of knowledge complementarity

Starting with the degenerate case (Figure D.1a) is the case of *no KC*. That is, the supply channel knowledge exchange is dependent on the knowledge input of only one of the dyad actors. For example, knowledge exchange levels KE_1 and KE_2 depend only on the knowledge contribution of actor **y** whereas KE_1' and KE_2' are dependent only on **x**. Knowledge sharing is not required in this exchange. A relationship in a no KC context would require sharing but likely would be transactional in nature (e.g. paid consulting relationships).

Channel-like KC (Figure D.1b) implies a body of knowledge that is not indigenous to either firm but components of which is supplied to the relationship at a fixed proportion for exchange

[14] modified from (Navon & Gopher, 1979)

to occur at a given level. This contribution *is* knowledge; however it is insufficient for the independent execution of the task. The productive capability exists only within the focal channel. If either party fails to contribute the requisite knowledge component then channel performance is degraded or precluded, while excessive contribution has no effect. For example, suppose the parties agree to KE_1 – a desired channel performance – which requires contribution x_1 from actor **x** and y_1 from actor **y.** Should actor **y** benevolently increase its contribution unilaterally to y_2, the channel performance does not increase. The surplus contribution alone cannot increase channel performance because it may be irrelevant to performance at that level or even incomprehensible to actor **x (**who may not be able to make use of the offered knowledge) – i.e., **x** may not possess the necessary absorptive capacity. However if both memebers of the dyad are willing and able to increase their respective contribution from (x_1,y_1) to $(x_2,y_{2)}$ then a higher level of exhange, KE_2, is possible.

Firm-like KC (Figure D.1c) is where the knowledge of either party may be independently sufficient for the execution of the task. However, for reasons not specific to the nature of the knowledge, the actor chooses to use knowledge from the partner instead of an internal source. There are two distinguishable types of firm-like KC: mostly firm-like (KE_1) and totally firm-like (KE_2). *Mostly firm-like* KC is where each of the actors has almost the entire knowledge base necessary for the product but may be missing a key capability. This is why in Figure 2c KE_1 does not have intercepts because the knowledge possessed by that firm is not complete. This missing competency could be indigenously developed at a cost as an alternative to a knowledge sharing relationship. *Totally firm-like* KC is when both actors do indeed possess the requisite knowledge but chose to still exchange knowledge in a dyadic relationship. This could, perhaps, reflect internal operational concerns such as resource allocation preferences, capacity constraints or economies of scale, etc.

As an example of totally firm-like KC, the former joint venture New United Motor Manufacturing, Inc. (NUMMI) between GM and Toyota was between two car manufactures either of which could have independently produced the product. However, both parties had goals beyond what were obtainable by sole utilization of their respective automobile production knowledge. GM wanted to learn the Toyota production system and Toyota wanted to establish a North American manufacturing presence ("What we're about ", 2007).

Partially substitutive KC (Figure D.1d) is a generalization of firm-like and channel-like KC. In channel-like KC *neither* firm is independently capable of process execution whereas in firm-like KC *either* firm is independently capable. Thus, partially substitutive KC is an intermediate position on a continuum bounded by channel-like and firm-like KC. Either, or both, members of the dyad have knowledge capabilities insufficient, or inefficient, for independent performance as in firm-like. However, unlike pure channel-like KC, the respective marginal knowledge contributions from each partner could be altered. Thus, a firm may enter into a partially substitutive supply channel relationship because the contribution required also enables it to develop a firm-like capability and the existing capability is such that it is not wholly dependent on the partner as in channel-like.

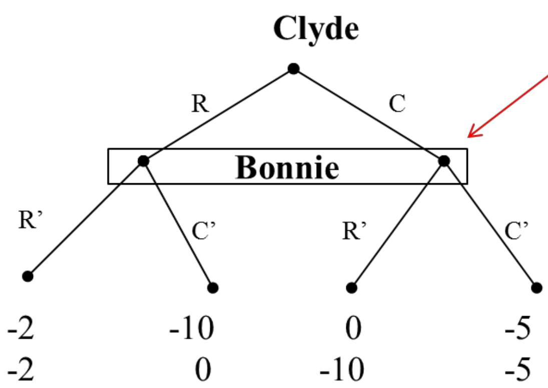
An excellent example of a partially substitutive exchange is the development of the LEAP-X1C engine for China's first domestically developed jumbo jet, the C919. The LEAP-X1C engine is based on technology developed by CFM International (a joint venture between GE and Snecma of France) and with final assembly and a test facility in China("CFM and ACAE Sign MOU for LEAP-X1C Assembly Line In China," 2009). The Chinese partner is the Aviation Industry Corporation of China's Commercial Aircraft Engine Company (ACAE division) who will supply many functions including research, development, airworthiness and customer service("Construction of China's jumbo jet engine base starts," 2010). In our framework, the development of the LEAP-X1C for the C919 airliner is substitutive because ACAE already has a near indigenous capability afforded by its existing smaller engines and extensive maintenance, repair and overhaul (MRO) business and CFM is a established player in the large engine market.

As the proportion of contribution from both firms is altered - perhaps for contractual, strategic or environmental reasons - there will be differential marginal requirements of both parties to hold output constant. Succinctly stated; $\partial KE/\partial y$ and $\partial KE/\partial x$ (where x and y are two firms) will change depending on the induced knowledge contribution from both actors. Thus, it becomes easier or more difficult for an actor to fulfill its obligation in the exchange.

Appendix E

Representations of payoffs in Game Theory

Extensive Form Game

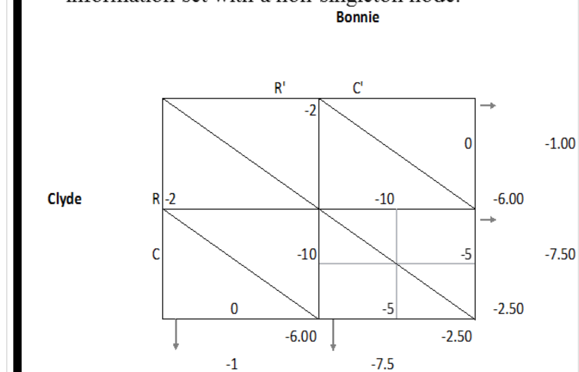


This is a static game. A **static** game is when each player acts at the same time and the game is played only once. A **dynamic** game is sequential and/or a static game played repeatedly where the players both know what happened in the last turn.

Normal Form Game

Bonnie does not know what Clyde has done because they make their decision at the same time or it is otherwise not known (as in a game of imperfect information).

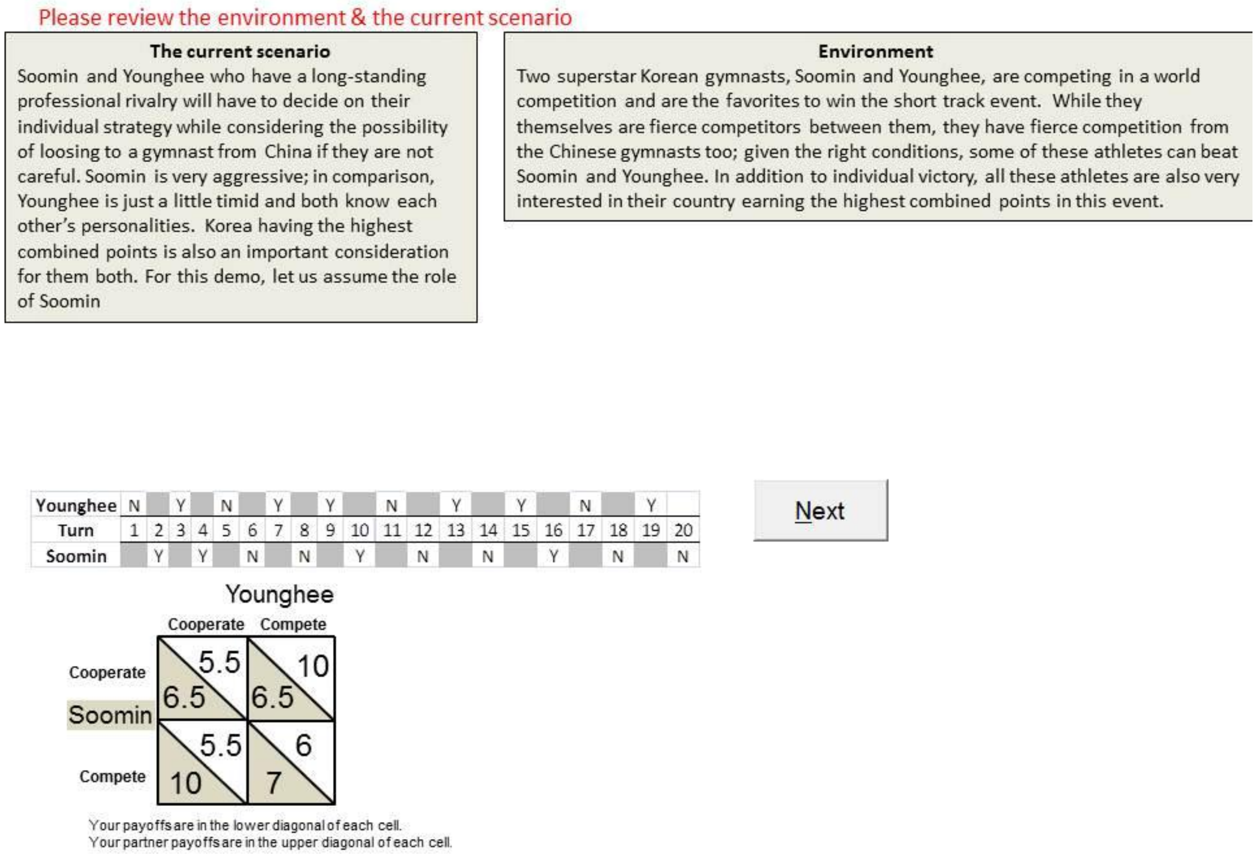
This is represented in extensive form games as an information set with a non-singleton node.



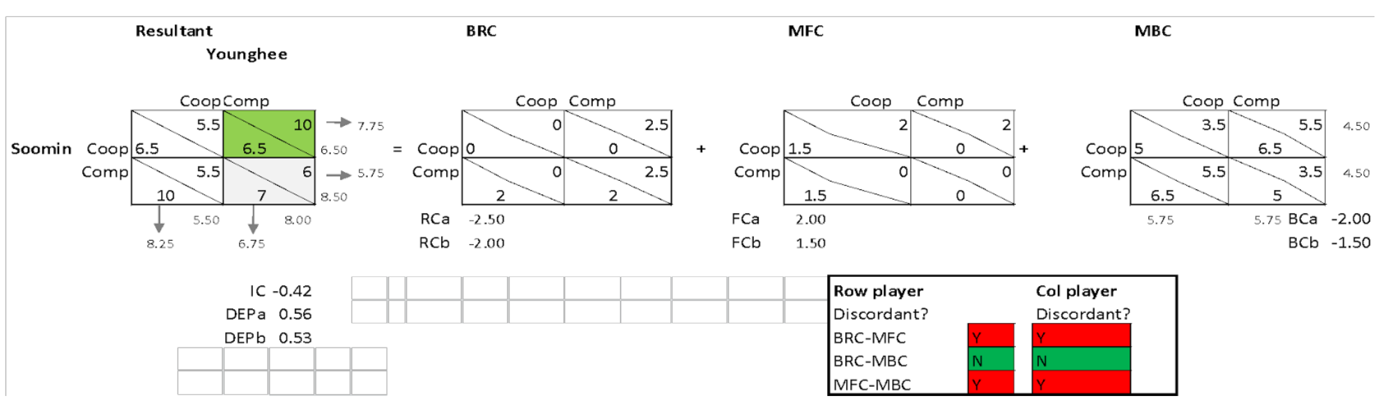
Appendix F

An example of a game with a deficient best payoff

An example used in the training scenario featured game 7 from Rapports' taxonomy of 2 x 2 games. It is a type 1 game where both actors have a dominant strategy and, for this particular game, a strongly stable equilibrium. The purpose for basing a scenario on this game is that the game theoretic solution is very different from the SET solution. Additionally, this specific game had 2 discordant pairs – BRC/MFC and MFC/MBC – around which a compelling narrative could be scripted. Thus, there are incentive conflicts while the resultant action pair depended on whether the players were acting out of self-interest of promoting the needs of the team. The screen shown below is the screen used during the training scenario and contains the payoff structure and the narrative that the participant is to use when making a decision on which action to choose.



The attraction of this specific game for training purposes is that the participants can be sensitized to the need to consider the context of the situation and not merely 'playing the numbers'. Next, the decomposition will be shown and the effects on the hypothesized behavior.



The game that Soomin and Younghee are playing is shown above along with the component matrices. The BRC-MFC pair is discordant for both gymnasts meaning that what each wishes to do is contrary to what her partner would want her to do. Further, the MFC-MBC component pair is discordant meaning that the coordination requirements impose a cost on both since the MBC matrix indicates that one gymnast should cooperate while the other competes.

While the MBC matrix is correspondent – they want to coordinate – the resultant matrix is not due to the component matrices. The overall result is that both gymnasts have internal incentive conflicts and do not have total goal congruence. Trying to compete to get her individual best outcome (bottom right cell in Figure) – the game theoretic solution – results in neither getting her own best outcome.

However, to achieve the best outcome for the team requires that the row actor (Soomin) sacrifice her best payoff allowing column (Younghee) to both achieve her best outcome *and* what is best for the team. To use a baseball analogy this would be equivalent to a batter making a *sacrifice fly* to enable a teammate to advance a base.

Appendix G

IRB Protocol Approval

Institutional Review Board - Federalwide Assurance #00003152
University of Cincinnati

Date: 5/29/2014
From: UC IRB

To: Principal Investigator: Fred Ahrens
COB Information Systems

Re: Study ID: 2013-6513
Study Title: Knowledge Exchange Behavior in Supply Channel Relationships

The above referenced protocol and all applicable additional documentation provided to the IRB were reviewed and **RE-APPROVED** using an **EXPEDITED** review procedure set forth in 45 CFR 46.110(b)(1), Category(ies)(see below) on 5/28/2014.

This study will be due for continuing review at least 30 days before 5/27/2015

Please note the following requirements:

AMENDMENTS: The principal investigator is responsible for notifying the IRB of any changes in the protocol, participating investigators, procedures, recruitment, consent forms, FDA status, or conflicts of interest. Approval is based on the information as submitted. New procedures cannot be initiated until IRB approval has been given. If you wish to change any aspect of this study, please submit an Amendment via ePAS to the IRB, providing a justification for each requested change.

CONTINUING REVIEW: The investigator is responsible for submitting a Continuing Review via ePAS to the IRB at least 30 days prior to the expiration date listed above. Please note that study procedures may only continue into the next cycle if the IRB has reviewed and granted re-approval prior to the expiration date.

UNANTICIPATED PROBLEMS: The investigator is responsible for reporting **unanticipated problems** promptly to the IRB via ePAS according to current reporting policies.

STUDY COMPLETION: The investigator is responsible for notifying the IRB by submitting a Request to Close via ePAS when the research, including data analysis, has completed.

Research Categories

Appendix H

H.1 One-way ANOVA: Q4 versus Hypothesis in Cluster H4b-H3b|H3a

Method

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
HypoClust1	6	H3a, H3b, H4a_Col, H4a_Row, H4b_Col, H4b_Row

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
HypoClust1	5	91.02	18.204	8.56	0.000
Error	238	505.88	2.126		
Total	243	596.90			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.45792	15.25%	13.47%	10.78%

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	Adjusted T-Value	P-Value
H3b - H3a	-0.382	0.267	(-1.149, 0.384)	-1.43	0.707
H4b_Col - H3a	-0.305	0.335	(-1.267, 0.656)	-0.91	0.943
H4b_Row - H3a	0.310	0.335	(-0.651, 1.271)	0.93	0.940
H4b_Col - H3b	0.077	0.350	(-0.928, 1.082)	0.22	1.000
H4b_Row - H3b	0.692	0.350	(-0.313, 1.698)	1.98	0.359
H4b_Row - H4b_Col	0.615	0.404	(-0.545, 1.776)	1.52	0.651

Individual confidence level = 99.55%

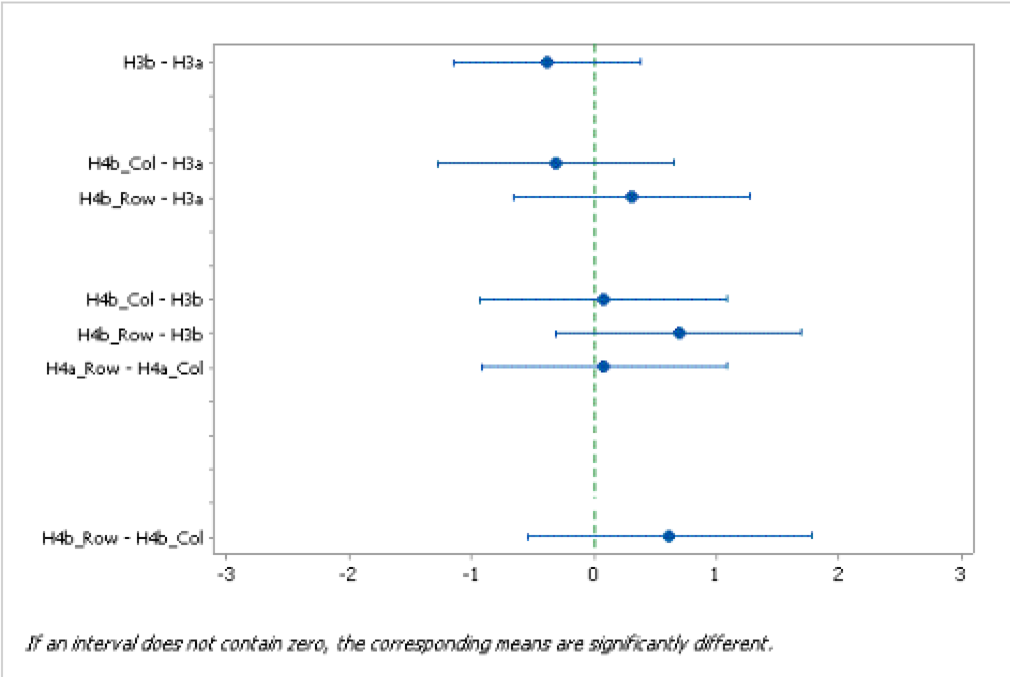


Figure H.1: BRC Component Means by Hypothesis for Cluster H4b-H3b|H3a

One-way ANOVA: Q5 versus Hypothesis in Cluster H4b-H3b|H3a

```
Method

Null hypothesis             All means are equal
Alternative hypothesis   At least one mean is different
Significance level          α = 0.05

Equal variances were assumed for the analysis.


Factor Information

Factor      Levels  Values
HypoClust1    6   H3a, H3b, H4a_Col, H4a_Row, H4b_Col, H4b_Row


Analysis of Variance

Source        DF   Adj SS   Adj MS   F-Value   P-Value
HypoClust1     5    62.07   12.413      5.49     0.000
Error        238   537.69    2.259
Total        243   599.75


Model Summary

      S      R-sq   R-sq(adj)   R-sq(pred)
   1.50306  10.35%       8.46%        5.45%
```

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	Adjusted T-Value	P-Value
H3b - H3a	0.585	0.275	(-0.205, 1.375)	2.12	0.278
H4b_Col - H3a	0.200	0.345	(-0.791, 1.191)	0.58	0.992
H4b_Row - H3a	-0.108	0.345	(-1.099, 0.883)	-0.31	1.000
H4b_Col - H3b	-0.385	0.361	(-1.421, 0.652)	-1.07	0.895
H4b_Row - H3b	-0.692	0.361	(-1.729, 0.344)	-1.92	0.394
H4b_Row - H4b_Col	-0.308	0.417	(-1.504, 0.889)	-0.74	0.977

Individual confidence level = 99.55%

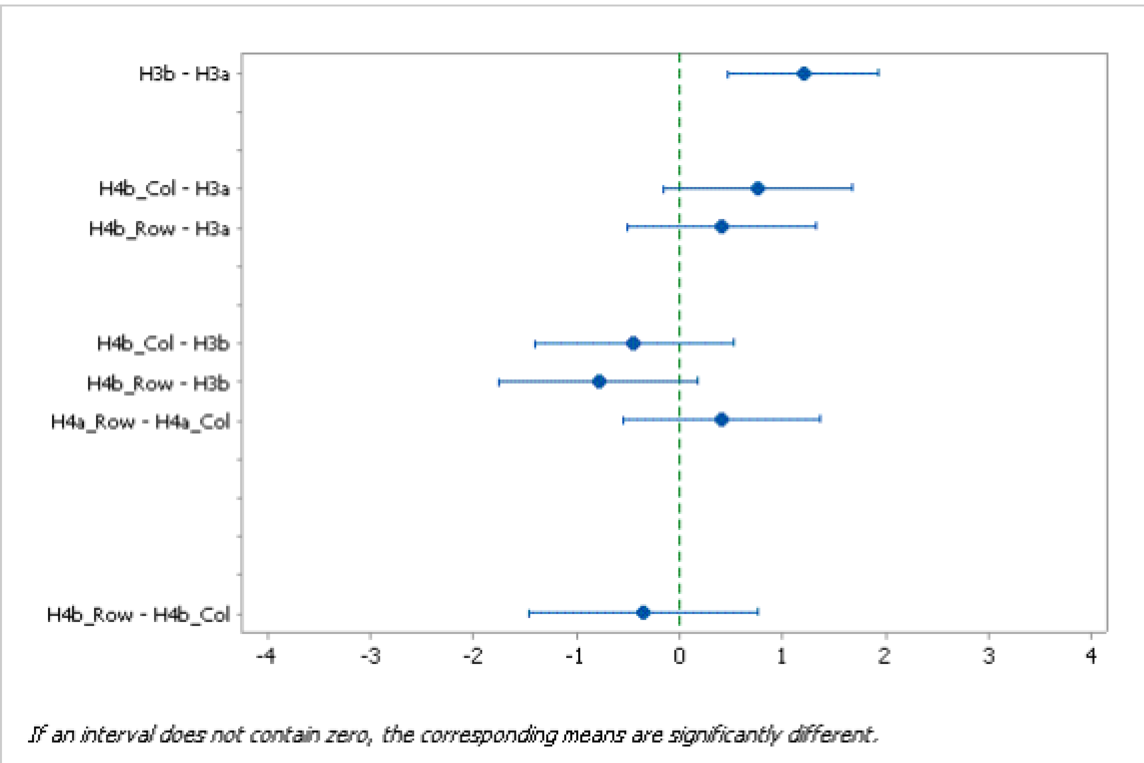


Figure H.2: MFC Component Means by Hypothesis for Cluster H4b-H3b|H3a

One-way ANOVA: Q6 versus Hypothesis in Cluster H4b-H3b|H3a

Method

Null hypothesis	**All means are equal**
Alternative hypothesis	**At least one mean is different**
Significance level	**α = 0.05**

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
HypoClust1	6	H3a, H3b, H4a_Col, H4a_Row, H4b_Col, H4b_Row

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
HypoClust1	5	260.5	52.100	26.99	0.000
Error	238	459.5	1.931		
Total	243	720.0			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.38945	36.18%	34.84%	33.01%

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	Adjusted T-Value	P-Value
H3b - H3a	1.204	0.254	(0.474, 1.934)	4.73	0.000
H4b_Col - H3a	0.762	0.319	(-0.155, 1.678)	2.39	0.165
H4b_Row - H3a	0.415	0.319	(-0.501, 1.332)	1.30	0.784
H4b_Col - H3b	-0.442	0.334	(-1.400, 0.516)	-1.33	0.771
H4b_Row - H3b	-0.788	0.334	(-1.747, 0.170)	-2.36	0.174
H4b_Row - H4b_Col	-0.346	0.385	(-1.452, 0.760)	-0.90	0.947

```
Individual confidence level = 99.55%
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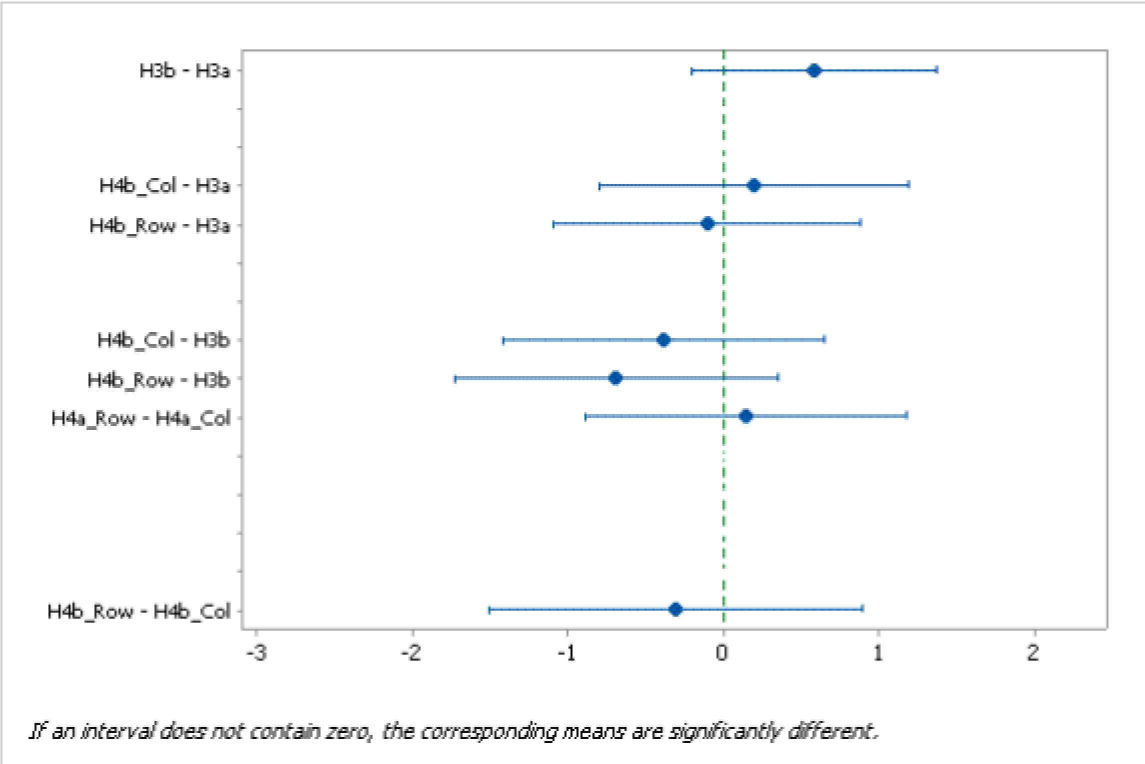

Figure H.3: MBC Component Means by Hypothesis for Cluster H4b-H3b|H3a

H.2 ANOVA for All Hypothesis

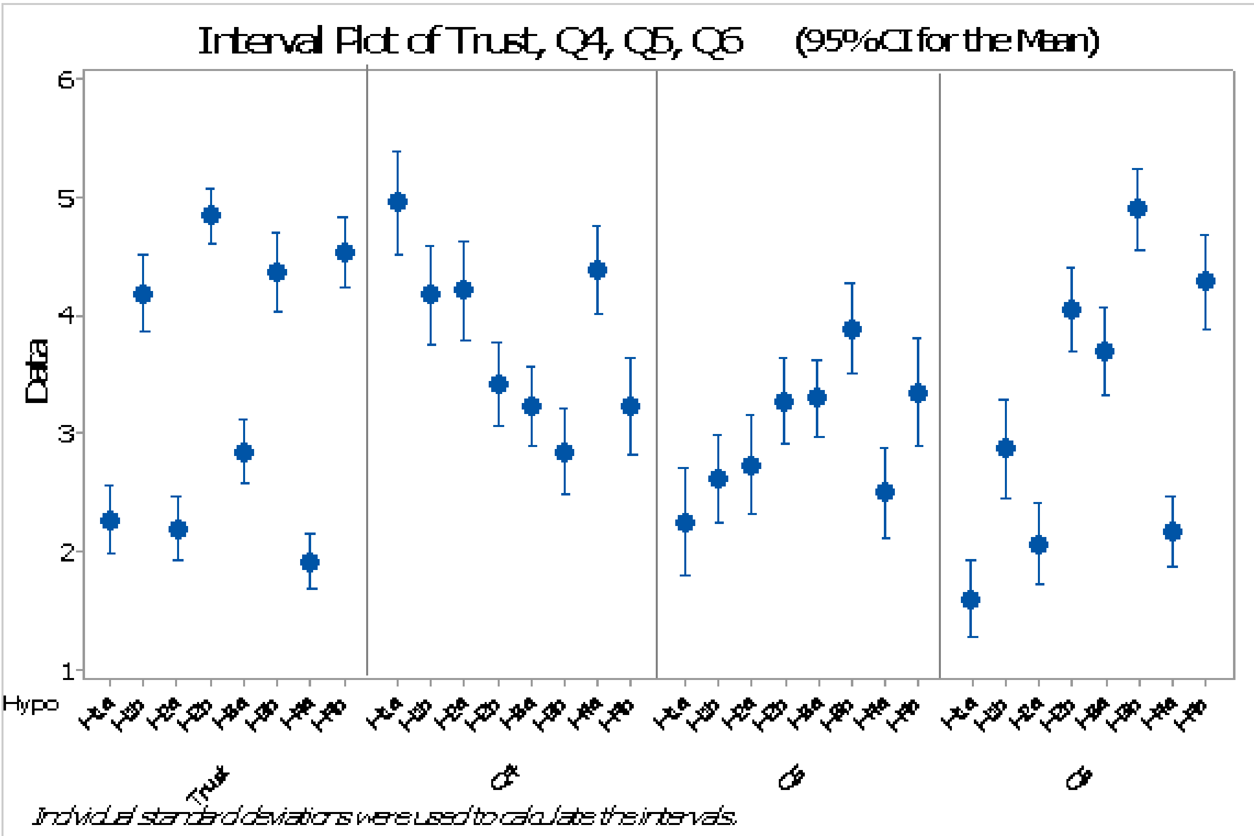

Figure H.4 Data Means for Self-reported Trust and Components

One-way ANOVA: Q4 versus Hypo

Method

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Hypo	8	H1a, H1b, H2a, H2b, H3a, H3b, H4a, H4b

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Hypo	7	210.1	30.008	12.95	0.000

```
Error   480  1112.5   2.318
Total   487  1322.5


Model Summary

      S    R-sq  R-sq(adj)  R-sq(pred)
1.52237  15.88%     14.66%      13.08%


Means

Hypo   N   Mean  StDev      95% CI
H1a   52  4.962  1.571  (4.547, 5.376)
H1b   70  4.171  1.753  (3.814, 4.529)
H2a   52  4.212  1.499  (3.797, 4.626)
H2b   70  3.414  1.469  (3.057, 3.772)
H3a   70  3.229  1.395  (2.871, 3.586)
H3b   52  2.846  1.319  (2.431, 3.261)
H4a   70  4.386  1.591  (4.028, 4.743)
H4b   52  3.231  1.490  (2.816, 3.646)

Pooled StDev = 1.52237


Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Hypo   N   Mean  Grouping
H1a   52  4.962  A
H4a   70  4.386  A
H2a   52  4.212  A B
H1b   70  4.171  A B
H2b   70  3.414    B C
H4b   52  3.231      C
H3a   70  3.229      C
H3b   52  2.846      C

Means that do not share a letter are significantly different.
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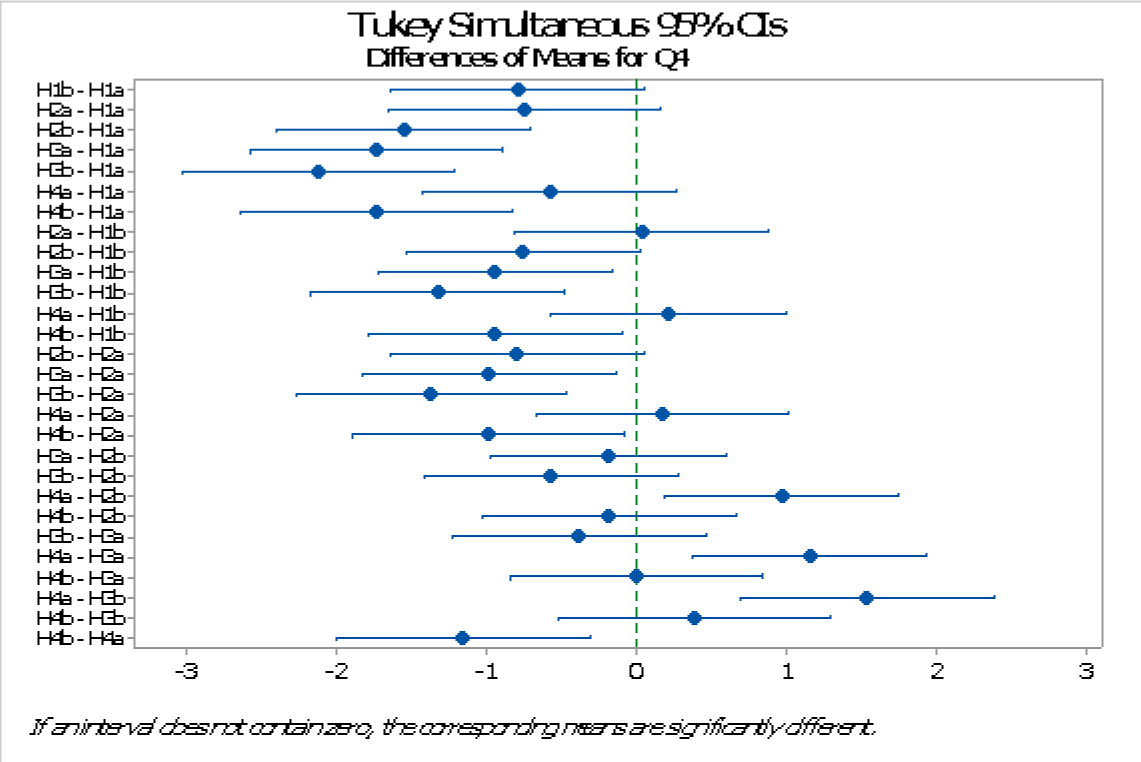

Figure H.5 Difference of Means for Q4 (BRC)

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H1b - H1a	-0.790	0.279	(-1.636, 0.055)	-2.83	0.087
H2a - H1a	-0.750	0.299	(-1.656, 0.156)	-2.51	0.190
H2b - H1a	-1.547	0.279	(-2.393, -0.702)	-5.55	0.000
H3a - H1a	-1.733	0.279	(-2.578, -0.888)	-6.22	0.000
H3b - H1a	-2.115	0.299	(-3.021, -1.210)	-7.09	0.000
H4a - H1a	-0.576	0.279	(-1.421, 0.270)	-2.07	0.437
H4b - H1a	-1.731	0.299	(-2.636, -0.825)	-5.80	0.000
H2a - H1b	0.040	0.279	(-0.805, 0.886)	0.14	1.000
H2b - H1b	-0.757	0.257	(-1.538, 0.023)	-2.94	0.065
H3a - H1b	-0.943	0.257	(-1.723, -0.162)	-3.66	0.006
H3b - H1b	-1.325	0.279	(-2.171, -0.480)	-4.76	0.000
H4a - H1b	0.214	0.257	(-0.566, 0.995)	0.83	0.991
H4b - H1b	-0.941	0.279	(-1.786, -0.095)	-3.38	0.017
H2b - H2a	-0.797	0.279	(-1.643, 0.048)	-2.86	0.081
H3a - H2a	-0.983	0.279	(-1.828, -0.138)	-3.53	0.010
H3b - H2a	-1.365	0.299	(-2.271, -0.460)	-4.57	0.000
H4a - H2a	0.174	0.279	(-0.671, 1.020)	0.62	0.999
H4b - H2a	-0.981	0.299	(-1.886, -0.075)	-3.28	0.023
H3a - H2b	-0.186	0.257	(-0.966, 0.595)	-0.72	0.996
H3b - H2b	-0.568	0.279	(-1.414, 0.277)	-2.04	0.456
H4a - H2b	0.971	0.257	(0.191, 1.752)	3.78	0.004
H4b - H2b	-0.184	0.279	(-1.029, 0.662)	-0.66	0.998
H3b - H3a	-0.382	0.279	(-1.228, 0.463)	-1.37	0.870
H4a - H3a	1.157	0.257	(0.377, 1.938)	4.50	0.000
H4b - H3a	0.002	0.279	(-0.843, 0.848)	0.01	1.000
H4a - H3b	1.540	0.279	(0.694, 2.385)	5.52	0.000

H4b - H3b	0.385	0.299	(-0.521, 1.290)	1.29	0.904
H4b - H4a	-1.155	0.279	(-2.000, -0.309)	-4.14	0.001

Individual confidence level = 99.75%

One-way ANOVA: Q5 versus Hypo

Method

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Hypo	8	H1a, H1b, H2a, H2b, H3a, H3b, H4a, H4b

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Hypo	7	119.1	17.009	7.29	0.000
Error	480	1119.7	2.333		
Total	487	1238.8			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.52731	9.61%	8.29%	6.57%

Means

Hypo	N	Mean	StDev	95% CI
H1a	52	2.250	1.619	(1.834, 2.666)
H1b	70	2.614	1.554	(2.256, 2.973)
H2a	52	2.731	1.510	(2.315, 3.147)
H2b	70	3.271	1.541	(2.913, 3.630)
H3a	70	3.300	1.355	(2.941, 3.659)
H3b	52	3.885	1.367	(3.468, 4.301)
H4a	70	2.500	1.604	(2.141, 2.859)
H4b	52	3.346	1.655	(2.930, 3.762)

Pooled StDev = 1.52731

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Hypo	N	Mean	Grouping
H3b	52	3.885	A
H4b	52	3.346	A B C
H3a	70	3.300	A B

H2b	70	3.271	A B C
H2a	52	2.731	B C D
H1b	70	2.614	B C D
H4a	70	2.500	C D
H1a	52	2.250	D

Means that do not share a letter are significantly different.

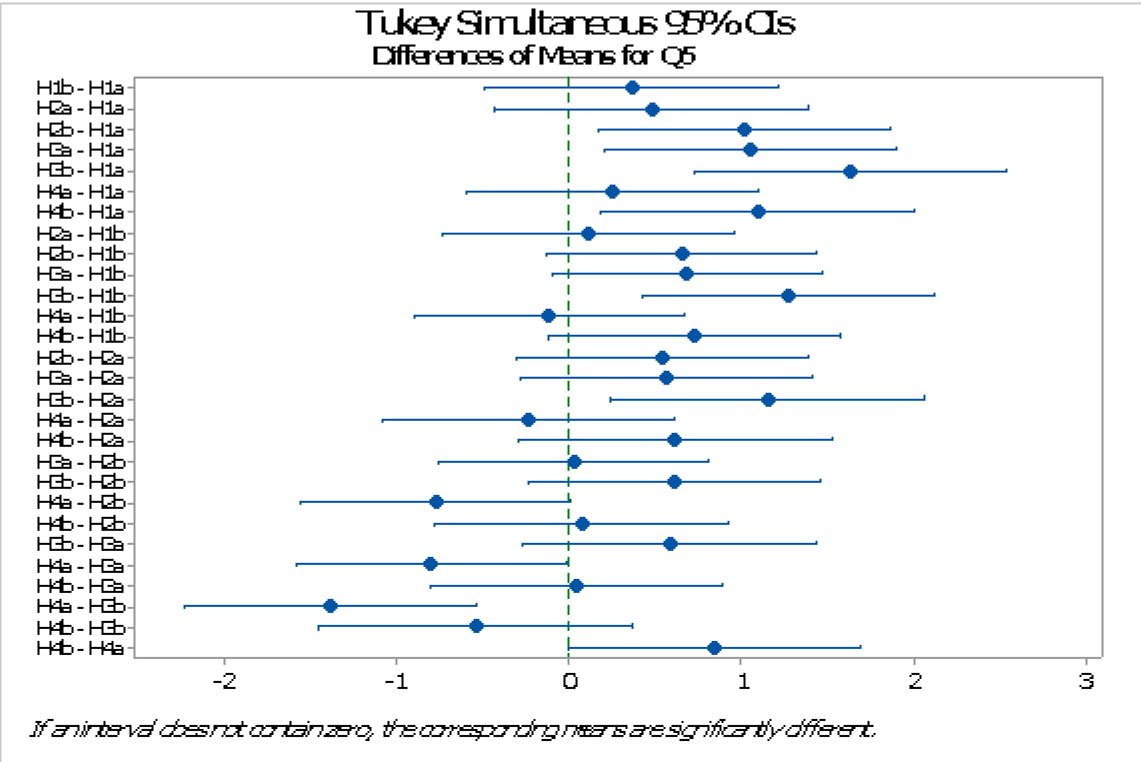

Figure H.6 Difference of Means for Q5 (MFC)

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H1b - H1a	0.364	0.280	(-0.484, 1.212)	1.30	0.898
H2a - H1a	0.481	0.300	(-0.428, 1.389)	1.61	0.747
H2b - H1a	1.021	0.280	(0.173, 1.870)	3.65	0.006
H3a - H1a	1.050	0.280	(0.202, 1.898)	3.76	0.004
H3b - H1a	1.635	0.300	(0.726, 2.543)	5.46	0.000
H4a - H1a	0.250	0.280	(-0.598, 1.098)	0.89	0.987
H4b - H1a	1.096	0.300	(0.188, 2.005)	3.66	0.006
H2a - H1b	0.116	0.280	(-0.732, 0.965)	0.42	1.000
H2b - H1b	0.657	0.258	(-0.126, 1.440)	2.55	0.176
H3a - H1b	0.686	0.258	(-0.097, 1.469)	2.66	0.136
H3b - H1b	1.270	0.280	(0.422, 2.119)	4.54	0.000
H4a - H1b	-0.114	0.258	(-0.897, 0.669)	-0.44	1.000
H4b - H1b	0.732	0.280	(-0.116, 1.580)	2.62	0.150
H2b - H2a	0.541	0.280	(-0.308, 1.389)	1.93	0.528
H3a - H2a	0.569	0.280	(-0.279, 1.417)	2.04	0.457
H3b - H2a	1.154	0.300	(0.245, 2.062)	3.85	0.003

H4a - H2a	-0.231	0.280	(-1.079, 0.617)	-0.83	0.992
H4b - H2a	0.615	0.300	(-0.293, 1.524)	2.05	0.445
H3a - H2b	0.029	0.258	(-0.755, 0.812)	0.11	1.000
H3b - H2b	0.613	0.280	(-0.235, 1.461)	2.19	0.356
H4a - H2b	-0.771	0.258	(-1.555, 0.012)	-2.99	0.057
H4b - H2b	0.075	0.280	(-0.773, 0.923)	0.27	1.000
H3b - H3a	0.585	0.280	(-0.264, 1.433)	2.09	0.421
H4a - H3a	-0.800	0.258	(-1.583, -0.017)	-3.10	0.041
H4b - H3a	0.046	0.280	(-0.802, 0.894)	0.17	1.000
H4a - H3b	-1.385	0.280	(-2.233, -0.536)	-4.95	0.000
H4b - H3b	-0.538	0.300	(-1.447, 0.370)	-1.80	0.622
H4b - H4a	0.846	0.280	(-0.002, 1.694)	3.03	0.051

Individual confidence level = 99.75%

One-way ANOVA: Q6 versus Hypo

Method

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Hypo	8	H1a, H1b, H2a, H2b, H3a, H3b, H4a, H4b

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Hypo	7	563.0	80.431	39.48	0.000
Error	480	977.9	2.037		
Total	487	1540.9			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.42733	36.54%	35.61%	34.46%

Means

Hypo	N	Mean	StDev	95% CI
H1a	52	1.596	1.159	(1.207, 1.985)
H1b	70	2.871	1.760	(2.536, 3.207)
H2a	52	2.058	1.243	(1.669, 2.447)
H2b	70	4.043	1.488	(3.708, 4.378)
H3a	70	3.700	1.582	(3.365, 4.035)
H3b	52	4.904	1.241	(4.515, 5.293)
H4a	70	2.171	1.251	(1.836, 2.507)
H4b	52	4.288	1.433	(3.900, 4.677)

Pooled StDev = 1.42733

```
Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Hypo   N   Mean  Grouping
H3b   52  4.904  A
H4b   52  4.288  A B
H2b   70  4.043    B
H3a   70  3.700    B
H1b   70  2.871      C
H4a   70  2.171      C D
H2a   52  2.058        D
H1a   52  1.596        D

Means that do not share a letter are significantly different.
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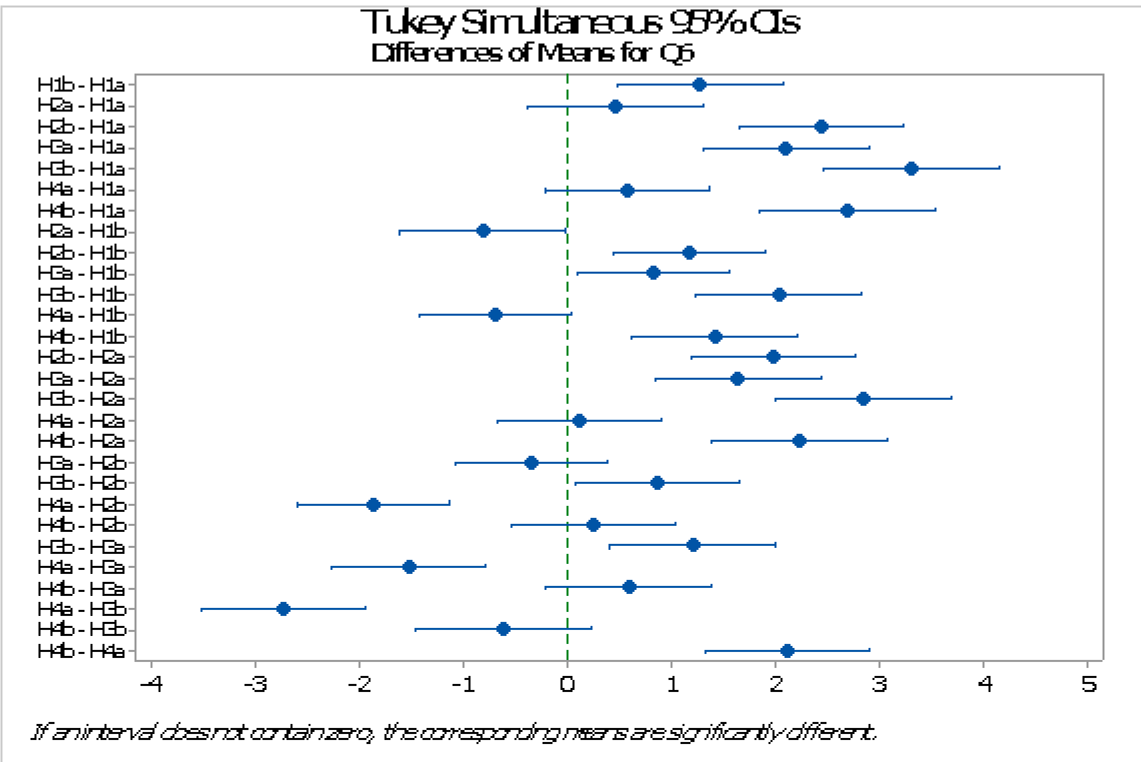

Figure H.7 Difference of Means for Q6 (MBC)

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H1b - H1a	1.275	0.261	(0.483, 2.068)	4.88	0.000
H2a - H1a	0.462	0.280	(-0.388, 1.311)	1.65	0.720
H2b - H1a	2.447	0.261	(1.654, 3.239)	9.36	0.000
H3a - H1a	2.104	0.261	(1.311, 2.897)	8.05	0.000
H3b - H1a	3.308	0.280	(2.459, 4.157)	11.82	0.000
H4a - H1a	0.575	0.261	(-0.217, 1.368)	2.20	0.351
H4b - H1a	2.692	0.280	(1.843, 3.541)	9.62	0.000
H2a - H1b	-0.814	0.261	(-1.606, -0.021)	-3.11	0.039
H2b - H1b	1.171	0.241	(0.440, 1.903)	4.86	0.000
H3a - H1b	0.829	0.241	(0.097, 1.560)	3.43	0.014
H3b - H1b	2.032	0.261	(1.240, 2.825)	7.78	0.000
H4a - H1b	-0.700	0.241	(-1.432, 0.032)	-2.90	0.072
H4b - H1b	1.417	0.261	(0.624, 2.210)	5.42	0.000
H2b - H2a	1.985	0.261	(1.192, 2.778)	7.60	0.000
H3a - H2a	1.642	0.261	(0.850, 2.435)	6.28	0.000
H3b - H2a	2.846	0.280	(1.997, 3.695)	10.17	0.000
H4a - H2a	0.114	0.261	(-0.679, 0.906)	0.44	1.000
H4b - H2a	2.231	0.280	(1.382, 3.080)	7.97	0.000
H3a - H2b	-0.343	0.241	(-1.075, 0.389)	-1.42	0.848
H3b - H2b	0.861	0.261	(0.068, 1.654)	3.29	0.022
H4a - H2b	-1.871	0.241	(-2.603, -1.140)	-7.76	0.000
H4b - H2b	0.246	0.261	(-0.547, 1.038)	0.94	0.982
H3b - H3a	1.204	0.261	(0.411, 1.997)	4.61	0.000
H4a - H3a	-1.529	0.241	(-2.260, -0.797)	-6.34	0.000
H4b - H3a	0.588	0.261	(-0.204, 1.381)	2.25	0.321
H4a - H3b	-2.732	0.261	(-3.525, -1.940)	-10.46	0.000
H4b - H3b	-0.615	0.280	(-1.465, 0.234)	-2.20	0.353
H4b - H4a	2.117	0.261	(1.324, 2.910)	8.10	0.000

Individual confidence level = 99.75%

One-way ANOVA: Trust versus Hypo

Method

Null hypothesis	All means are equal
Alternative hypothesis	At least one mean is different
Significance level	$\alpha = 0.05$

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Hypo	8	H1a, H1b, H2a, H2b, H3a, H3b, H4a, H4b

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Hypo	7	623.4	89.054	72.46	0.000
Error	480	589.9	1.229		
Total	487	1213.3			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
1.10859	51.38%	50.67%	49.76%

Means

Hypo	N	Mean	StDev	95% CI
H1a	52	2.269	1.031	(1.967, 2.571)
H1b	70	4.186	1.365	(3.925, 4.446)
H2a	52	2.192	0.951	(1.890, 2.494)
H2b	70	4.843	1.002	(4.583, 5.103)
H3a	70	2.843	1.137	(2.583, 3.103)
H3b	52	4.365	1.221	(4.063, 4.667)
H4a	70	1.914	1.004	(1.654, 2.175)
H4b	52	4.538	1.056	(4.236, 4.841)

Pooled StDev = 1.10859

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Hypo	N	Mean	Grouping			
H2b	70	4.843	A			
H4b	52	4.538	A	B		
H3b	52	4.365	A	B		
H1b	70	4.186		B		
H3a	70	2.843			C	
H1a	52	2.269			C	D
H2a	52	2.192				D
H4a	70	1.914				D

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
H1b - H1a	1.916	0.203	(1.301, 2.532)	9.44	0.000
H2a - H1a	-0.077	0.217	(-0.736, 0.583)	-0.35	1.000
H2b - H1a	2.574	0.203	(1.958, 3.189)	12.68	0.000
H3a - H1a	0.574	0.203	(-0.042, 1.189)	2.83	0.089
H3b - H1a	2.096	0.217	(1.437, 2.756)	9.64	0.000
H4a - H1a	-0.355	0.203	(-0.971, 0.261)	-1.75	0.655
H4b - H1a	2.269	0.217	(1.610, 2.929)	10.44	0.000
H2a - H1b	-1.993	0.203	(-2.609, -1.378)	-9.82	0.000
H2b - H1b	0.657	0.187	(0.089, 1.226)	3.51	0.011
H3a - H1b	-1.343	0.187	(-1.911, -0.774)	-7.17	0.000
H3b - H1b	0.180	0.203	(-0.436, 0.795)	0.89	0.987
H4a - H1b	-2.271	0.187	(-2.840, -1.703)	-12.12	0.000
H4b - H1b	0.353	0.203	(-0.263, 0.968)	1.74	0.662
H2b - H2a	2.651	0.203	(2.035, 3.266)	13.06	0.000
H3a - H2a	0.651	0.203	(0.035, 1.266)	3.21	0.029
H3b - H2a	2.173	0.217	(1.514, 2.833)	10.00	0.000
H4a - H2a	-0.278	0.203	(-0.894, 0.338)	-1.37	0.871
H4b - H2a	2.346	0.217	(1.687, 3.006)	10.79	0.000

H3a - H2b	-2.000	0.187	(-2.568, -1.432)	-10.67	0.000
H3b - H2b	-0.477	0.203	(-1.093, 0.138)	-2.35	0.265
H4a - H2b	-2.929	0.187	(-3.497, -2.360)	-15.63	0.000
H4b - H2b	-0.304	0.203	(-0.920, 0.311)	-1.50	0.808
H3b - H3a	1.523	0.203	(0.907, 2.138)	7.50	0.000
H4a - H3a	-0.929	0.187	(-1.497, -0.360)	-4.96	0.000
H4b - H3a	1.696	0.203	(1.080, 2.311)	8.35	0.000
H4a - H3b	-2.451	0.203	(-3.067, -1.835)	-12.08	0.000
H4b - H3b	0.173	0.217	(-0.486, 0.833)	0.80	0.993
H4b - H4a	2.624	0.203	(2.009, 3.240)	12.93	0.000

Individual confidence level = 99.75%